THE EFFECTS OF VIDEO-BASED AND ACTIVITY-BASED INSTRUCTION ON HIGH SCHOOL STUDENTS' KNOWLEDGE, ATTITUDES, AND BEHAVIORAL INTENTIONS RELATED TO SEAT BELT USE

By

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Abstract of Dissertation Presented to the Graduate School
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THE EFFECTS OF VIDEO-BASED AND ACTIVITIY-BASED INSTRUCTION ON HIGH SCHOOL STUDENTS' KNOWLEDGE, ATTITUDES, AND BEHAVIORAL INTENTIONS RELATED TO SEAT BELT USE

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The purpose of this study was to determine the effect of video-based science instruction and accompanying activity-based instruction on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts. Secondarily, the purpose was to determine order effects and interactions between the two treatments used in the study: video-based instruction and hands-on activity-based instruction. The study used Ajzen and Fishbein's theory of reasoned action to investigate the factors influencing high school students' behavioral intentions regarding seat belt use.

This study used a pretest-posttest-posttest treatment design. Data were collected on 194 students in high school introductory biology and chemistry classes in Gainesville, Florida. Ten intact high school science classes (eight treatment and two control) took pretests and posttests measuring physics knowledge, attitudes, and behavioral intentions toward seat belt use prior to and after participating in the two treatments. The treatment group students participated in at least 500 minutes of instructional time divided among five lessons over 10 instructional days. All participants were pretested on physics knowledge, attitudes, and behavioral intentions toward seat belt use prior to two treatments. Treatment A was defined as participating in one 50-minute video-based instructional lesson. Treatment B was defined as participating in four hands-on science activities regarding crash-related physics concepts.

Cronbach's coefficient alpha was used for analysis of the researcher-designed instruments, and ANOVA was used to analyze the data. The results of the analyses ($p<.004$) revealed that students who participated in either treatment showed significant differences in knowledge gains on 75% of the test items. The sequence of treatments did not produce significant differences in groups' posttest 2 knowledge mean scores. Combining the treatments resulted in higher mean knowledge scores than either treatment did individually. Participating in video-based instruction initially produced significant changes in students' attitudes but these changes were not maintained after students completed the activity-based instruction. Each treatment and the combined treatments resulted in significantly greater ($p<.05$) positive shifts in behavioral intentions regarding seat belts use. The treatment sequence did not result in significantly greater ($p<.05$) positive shifts in behavioral intentions regarding seat belt use.

The results of this study indicate that video-based instruction and activity-based instruction can positively change knowledge and behavioral intentions related to seat belt use, thereby potentially saving the lives of young adults.

CHAPTER 1
INTRODUCTION

Automobile collisions involving young drivers between the ages of 16-19 have been a worldwide road safety and public health concern for decades (Mayhew & Simpson, 1996). In the United States, motor vehicle-related injuries are the largest health problem for 16-19-year-olds, accounting for more than one-third of all deaths in this age group (Williams, 1995). Research shows that current driver education programs have been unable to affect the crash risk of young drivers and, therefore, the safety value of these programs remains unproven (Mayhew & Simpson, 1996). The dialogue between the research community and educators has often been bitter; consequently, little has been done in the past 50 years to change the educational approach of driver training (Palmer, 1995).

Recently, however, a cooperative spirit is defining the search for innovative ways to improve driver education (Simpson, 1995). One of the many recommendations agreed upon is to examine not only what is taught in driver education but how it is taught. The Traffic Injury Research Foundation believes the content and delivery of driver education should be reviewed; "the curriculum should include experiences that demonstrate the value of safety practices and thereby motivate novices to drive safely" (Mayhew & Simpson, 1996, p. 81). In an attempt to motivate students through fear, older curricula often tried to provide these experiences through extremely graphic videos depicting actual crash victims, such as Mechanized Death, funded by the U. S. Department of

Transportation in 1965. This study takes a theoretically different approach to driver education by using a science educational video and accompanying hands-on science activities as the vehicle to support the rationale for using seat belts.

Purpose of the Study

The purpose of this study was to determine the effect of video-based science instruction and accompanying activity-based instruction on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts. The study used Ajzen and Fishbein's (1980) theory of reasoned action to investigate the factors influencing high school students' behavioral intentions regarding seat belt use.

Rationale for the Study

To further the use of attitude and intended behavior research in science education and traffic injury research this study used a theoretical approach to identify the factors associated with predicting students' intentions to use safety belts. In addition to the application of the theory of reasoned action, this study also gathered data for future studies on the influence of several external variables (i.e., gender, grade level, race/ethnicity, and socioeconomic status) that have long been associated with traffic injury research and have shown promise in explaining group differences. Furthermore, this study lends justification to the important relationship among knowledge, attitudes, and behavioral intentions in science education and provides a new perspective in the field of traffic safety.

Research Hypotheses

The following twelve research hypothesis were investigated in this study:

1. After participating in video-based instruction, students will have significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

2. After participating in video-based instruction, students will have significant positive changes in attitudes regarding seat belt use.
3. After participating in video-based instruction, students will have significant positive changes in behavioral intentions regarding seat belt use.
4. After participating in activity-based instruction, students will have significant gains in knowledge regarding the physics of car crashes relating to seat belt use.
5. After participating in activity-based instruction, students will have significant positive changes in attitudes regarding seat belt use.
6. After participating in activity-based instruction, students will have significant positive changes in behavioral intentions regarding seat belt use.
7. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in significant gains in knowledge regarding the physics of car crashes relating to seat belt use.
8. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in significant positive changes in attitudes regarding seat belt use.
9. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in significant positive changes in behavioral intentions regarding seat belt use.
10. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in significantly greater knowledge gains regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based instruction second.
11. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in significantly greater positive changes in attitudes regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based instruction second.
12. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in significantly greater positive shifts in behavioral intentions regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based instruction second.

Definition of Terms

Terms used in this study are defined below.

Attitude is defined as a bipolar evaluative judgment indicating the amount of affect for or against an object or behavior. An attitude is a positive or negative feeling about a particular object or behavior. A more comprehensive definition of attitude may be found in Chapter Two.

Attitude toward the behavior "represents a person's general feeling of favorableness or unfavorableness toward some behavior" (Crawley & Coe, 1990, p. 464). Behavioral beliefs and evaluation of the outcomes of these beliefs influence the formation of attitudes (Ajzen & Fishbein, 1980).

Behavioral intention can best be defined by first defining behavior. Behavior is defined as "an overt action under the volitional control and within the individual's capability" (Crawley & Coe, 1990, p. 463). Hence, behavioral intention can be defined as an individual's plan to act in a particular fashion. From the theory of reasoned action, behavioral intention is the weighted addition of attitudes toward behavior and subjective norms. Since behavioral intention is a plan to act or perform a particular behavior, it can be said that behavioral intention and behavior are closely related (Ajzen & Fishbein, 1980).

Crashworthiness refers to how well a vehicle protects people in a crash. The principal component of a vehicle's crashworthiness evaluation, as determined by the Insurance Institute for Highway Safety, is its performance in a 40-mph frontal offset crash. Each vehicle's offset crash test performance and overall evaluation is based on the following five criteria: 1) structure/safety cage intrusion, 2) injury measures obtained from a 50th percentile male Hybrid III crash-test dummy in the driver seat, 3) amount of restraint/dummy movement, 4) head restraint quality, and 5) bumper repair costs with a 5 mph collision.

Driver education refers to in-class instruction, which teaches not only specific skills, but learning strategies, attitudes and motivations.

Driver training refers to in-vehicle instruction, which teaches the practical features of manipulating the vehicle and the perceptual motor responses required in driving. Most high school driver education programs incorporate some form of driver education and driver training in preparing beginning drivers.

Normative beliefs of important others are an individual's beliefs about what important others (referents) feel the individual should or should not do. These are measured on bi-polar "I should–I should not" scales in which the subjects indicate the likelihood that each relevant other thinks the subject should or should not perform the behavior.

Motivation to comply with the important others is an individual's incentive to conform to what relevant others feel the individual should do. These are measured by having subjects rate their motivations to comply with each relevant other on bi-polar scales "I want to do–I do not want to do" endpoints (Page, 1982).

Subjective norm "represents the perception one holds about the social pressures to engage or not engage in a behavior" (Crawley & Coe, 1990, p. 464). Normative beliefs and motivations to comply with particular referents shape the subjective norm (Ajzen & Fishbein, 1980).

The theory of reasoned action is a social, psychological theoretical model that predicts a person's behavioral intentions from his or her beliefs, evaluations, normative beliefs, and motivations to comply (Ajzen & Fishbein, 1980).

Assumptions

The following assumptions apply to the study:

1. The students who participated in the study adequately represent the population of ninth and tenth graders in the United States.
2. The questionnaires and instruments used were adequate for data collection.
3. The students who participated in the study completed the questionnaires and instruments truthfully and to the best of their abilities.
4. The students' motivation and candor were adequate for the purpose of the proposed study.
5. It was assumed that using a safety belt while driving or riding in an automobile is a desirable behavior.

Delimitations and Limitations of the Study

The delimitations of the study were as follows:

1. The participants in the study were ninth and tenth graders at a university laboratory school in northeast Florida.
2. Students could not be randomly assigned for the investigation; thus intact classes were used for cluster random sampling.

The limitations of the study were as follows:

1. All subjects participated on a voluntary basis.
2. The data obtained depended on the accuracy of self-reporting by the ninth and tenth grade participants.
3. No follow-up assessment was used to document the students' actual change in behavior; only behavioral intentions were assessed.

Significance of the Study

Research on knowledge, attitudes, and intended behaviors in traffic injury research is extremely important because of the ramifications of results from such studies. The findings from these studies can be instrumental in understanding and predicting young drivers' intentions to use safety belts. If it can be proven that a particular strategy is more effective in changing students' intended behaviors to wear safety belts, the vehicle education community will have a better idea of how to best utilize resources and efforts. Paczolt (1991) reported that the ability to predict safety belt use in teenagers would undoubtedly lead to the development of educational programs that could have a greater impact on the population. Such understanding and predictive ability could lead to additional lives saved (United States Department of Health and Human Services, 1991).

As part of driver education programs for teenagers, there is a move to broaden the concept of students' driving experience from direct driving skills to a larger matrix of experiential factors (e.g., hands-on science experiences) that are relevant to the development and behavior of young people (Simpson, 1996). During the First Annual International Symposium of the Youth Enhancement Service (held in June, 1995), researchers agreed on the need to recognize the potential importance of this array of experiences to driving and to determine its relevance empirically (Simpson, 1996).

This study examined the effectiveness of using learning experiences in a high school science classroom to expose students to vehicle safety concepts. It also analyzed the effects of such experiences on students' knowledge, attitudes, and behavioral intentions toward seat belt use. An educational science video was developed to address vehicle safety issues by providing viewers with many visual experiences designed to illustrate the physics concepts involved in car crashes. The videotape was complemented with a set of teacher-guided, hands-on science activities. These were designed to provide opportunities for direct experience with key crash-related motion concepts of inertia, energy, momentum, and impulse.

As Simpson summarizes, "Given the rather disappointing results of evaluations conducted to date on the effectiveness of driver education/training, two issues become salient. The first concerns the potential role that education might be able to play as a traffic safety countermeasure, if modified in some way. The second related issue involves the specific role that education can play in a graduated licensing system" (Simpson, 1996). Addressing the first concern, this study contends that a fundamental shift in driver education pedagogy toward proven science instructional methods can change students' knowledge, attitudes and intended behaviors related to traffic safety and seat belt use.

To address the second concern, this study contends the science education community can play a key role in contributing to the success of graduated licensing programs. Graduated licensing systems are multiphased, typically involving a two- or three-stage process designed to phase-in young beginners to full driving privileges as they mature and develop their driving skills. The graduated licensing approach is based on the premise that beginning drivers are so overwhelmed with maintaining basic control of the vehicle that safe driving concepts cannot be learned and applied (Mayhew & Simpson, 1996). The National Highway and Traffic Safety Administration's (NHTSA) graduated licensing model recommends two stages of driver education: a basic driver education course in the first or learner stage and an advanced driver education course in the second stage. This study's science video and accompanying hands-on activities could support the more advanced safety-oriented course during the second stage of NHTSA's model.

In summary, there are four interrelated lines of argument that establish the significance of this study. First, the study advances knowledge in the fields of science education and traffic injury research. Second, it contributes to the development of more effective driver education curricula and practices. Third, it demonstrates a novel use of a proven effective instructional strategy. And fourth, it is part of a programmatic research effort to reduce young adult injuries and fatalities in vehicle collisions.

CHAPTER 2
REVIEW OF RELATED LITERATURE

Overview

The purpose of this chapter is to provide a summary and analysis of the professional literature related to the issue addressed in this study: determining the effect of an educational science video and accompanying hands-on science activities on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts. This chapter includes a summary of research related to the following six topics: (a) hands-on science activities and learning, (b) attitudes and learning, (c) Ajzen and Fishbein's theory of reasoned action, (d) instructional technology, (e) adolescent seat belt use, and (f) the safety impact of driver education. Finally, a summary and review of implications of past research for the design of this investigation is provided.

Hands-On Science Activities and Learning

Research findings from the last two decades have shown growing support for the proposal that integrated and meaningful types of knowledge are best learned when what occurs in schools is less receptional and more transformational (Krajcik, Czerniak, & Berger, 1999). Receptional approaches are the more traditional approaches in which information is transmitted by the teacher for the students to receive passively. Transformational approaches to teaching are those in which students actively learn by constructing new knowledge and integrating it with their existing worldview. Many cognitive theorists have argued that knowledge is in part a product of the context, activity, and culture in which it was developed and applied (Ausubel, 1963; Dewey, 1933; Piaget, 1972; Schwab, 1973; Tobin, 1988; Vygotsky, 1986).

These researchers see knowledge as contextualized; thus it is not easily separated from the situation in which it was developed. The National Science Education Standards (National Research Council [NRC], 1996) state, "Student understanding is actively constructed through individual and social processes. In the same way that scientists develop their knowledge and understanding as they seek answers to questions about the natural world, students develop an understanding of the natural world when they are actively engaged in scientific inquiry–alone and with others" (p.29). This theory of learning that suggests new knowledge is constructed by making connections between new information presented and the existing conceptual framework is often referred to as social constructivism (Ausubel, 1963; Novak, 1979; Shapiro, 1994; Tobin, 1993; Vygotsky, 1986).

The social constructivist learning theory asserts that students take an active role in constructing their knowledge. Accordingly, a model of teaching science that utilizes social constructivist theory requires students to mindfully interact with concrete materials, often referred to as hands-on science activities. Supporters of hands-on science activities maintain students retain more of what they are taught if they engage in more active, concrete types of learning. Bruner (1977) argued that the more active and concrete children's learning is, the more they retain. Dale's Cone of Experience (Figure 1) provides educators with a visual tool for comparing how various teaching strategies use concrete materials and their correlation to estimated percentage of retention and level of involvement with concrete materials by students (Dale, 1969). The question can be

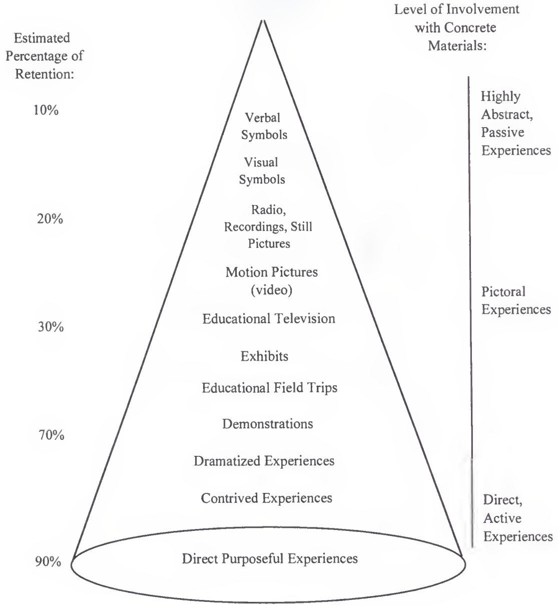

Estimated Percentage of Retention:
10%
20%
30%
70%
90%
Verbal Symbols
Visual Symbols
Radio, Recordings, Still Pictures
Motion Pictures (video)
Educational Television
Exhibits
Educational Field Trips
Demonstrations
Dramatized Experiences
Contrived Experiences
Direct Purposeful Experiences
Level of Involvement with Concrete Materials:
Highly Abstract, Passive Experiences
Pictoral Experiences
Direct, Active Experiences

Figure 1. Dale's Cone of Experience

asked: Do hands-on science activities provide the appropriate, direct, purposeful experiences for learning new physics/vehicle collision concepts based on the social constructivist learning theory?

A guiding principle of social constructivism is that questions or topics must be relevant to students (Krajcik, Czerniak, & Berger, 1999). Novak (1979) argued that concepts are not isolated; they depend on meaningful relationships with other concepts, context, and the learner's cognitive structure. In a summary of the literature, Blumenfeld, Soloway, Marx, Krajcik, Guzdial, and Palincsar (1991) reported that student interests are enhanced when (a) tasks are varied and include novel elements, (b) problems are authentic and valuable, (c) problems are challenging, (d) there is closure through the creation of a product, (e) there is choice about what and/or how work is done, and (f) there are opportunities to work with others. Again, the question can be asked: Do hands-on science activities facilitate the learning of new physics/vehicle collision concepts by making the process more interesting and relevant to students?

Ledbetter (1993) reported hands-on activity participation does not guarantee concept learning without additional interventions to tie the important science concepts to the hands-on activities. He found that while some hands-on activities are meaningful to those completing the activity, many activities lack relevance to the students, and thus, learning of the concept might not occur. Ledbetter's study investigated teachers' understanding of force and motion concepts as a result of exposure to a set of videotapes and complementary hands-on activities. He found exposure to the videotapes produced greater gains in posttest scores than sole exposure to hands-on activities. The videotapes appeared effective and efficient in providing the additional interventions to link the important science concepts to the hands-on activities (Ledbetter, 1993).

This current study hypothesized that high school students who experienced video-based instruction with accompanying activity-based instruction would show significant gains in scores on a posttest measuring knowledge of the physics of car crashes related to seat belt use.

Attitudes and Learning

Most educational objectives can be classified into three major learning domains: cognitive, affective, and psychomotor (Krathwohl, Bloom, & Masia, 1964). The cognitive domain refers to knowledge/beliefs of the facts and concepts of a particular field. The affective domain is a combination of attitudes, values, and emotions. The psychomotor domain refers to the physical movements in learning and thinking and problem solving skills. Of the three, the affective domain has received the least attention in science education research (Koballa, 1988). Research on the affective domain was often neglected in the past due to its perceived link with indoctrination and the difficulties in developing reliable and valid evaluations (LaForgia, 1988). As the concept of attitude in the affective domain has evolved, so has the ability to measure it.

Knowledge, Attitudes, and Values

Defining the term attitude has daunted social psychologists, including science educators, for years (Laforgia, 1988). The concept of attitude originated in the early 20th century. Previously, attitude had been considered more a physical concept than a psychological one (Shrigley, Koballa & Simpson, 1988). Fishbein and Ajzen (1975) contend "most investigators would probably agree that attitude can be described as a learned predisposition to respond in a consistently favorable or unfavorable manner toward an attitude object" (p. 6). Koballa (1988) agrees with Fishbein and Ajzen and brings the definition to its present status with his assessment:

> One common view of attitude in the past was that it had three components: a cognitive component, consisting of the person's belief's about an object; an affective component, consisting of a person's feeling about the object; and a cognitive component, consisting of a person's intentions to act in a particular way toward the object. This view is now less widely accepted by attitude theorists, at least in part because it clouds some important distinctions between the concepts.

> As currently conceived and operationalized, the affective component of the trilogy is the sole attribute of the concept. (p. 121)

Fishbein and Ajzen (1975) explained the distinction between attitude and belief in the following manner: "Whereas attitude refers to a person's favorable or unfavorable evaluation of the object, beliefs represent the information he has about the subject. Specifically, a belief links an object to some attribute" (p. 12). Since beliefs are representative of information or knowledge one has on a subject, this knowledge can have different levels of strength and can be factual or nonfactual. Therefore, Fishbein and Ajzen (1975) contend that beliefs form the basis of attitudes, with the attitude being negative or positive depending on the strength of the set of beliefs.

Values, on the other hand, are generated from our environment, be it our culture, subculture and social class (Koballa, 1988), or our experiences (Rokeach, 1969). Rokeach (1970) and McGee (1980) describe values as being more general than attitudes since they lack a specific object and are content-free. While attitudes are seen as being bidirectional, positive or negative with degrees of strength in either direction, values are seen as unidirectional and positive in nature. Rokeach (1976) further claims that while a person may have thousand of attitudes, he or she has only a few dozen values.

While both attitudes and values can be evaluated, values are more persistent and complex. Thus, values are more difficult to change than attitudes. However, values are important to educators "because of the crucial role they play in mediating a multitude of attitudes" (Koballa, 1988, p. 120). For example, if a student values his/her own safety and the safety and well-being of others, then it may be possible for that student to develop a positive attitude toward the use of safety belts, responsible driving habits, or vehicle selection.

Linking Knowledge, Attitudes, and Behavior

Many research studies have reported strong correlations between attitudes toward a particular behavior and the behavior itself (Wiegel & Newman, 1982). One major theory proposed to explain the attitude-behavior relationship was the theory of planned behavior (Eiser, 1986). First proposed by Icek Ajzen in 1985, this theory is an extension of the theory of reasoned action. In the theory of planned behavior, an additional antecedent is added to the two determinants used to predict behavioral intention in the theory of reasoned action model. This additional variable is called "perceived behavioral control," which is defined as "the person's belief as to how easy or difficult performance of the behavior is likely to be" (Ajzen & Madden, 1986, p. 457). If perceived behavioral control is irrelevant or inappropriate, then the theory of planned behavior reduces to the theory of reasoned action. The theory of planned behavior has been used to successfully predict college students' attendance of class lectures and earning an "A" in a course (Ajzen & Madden, 1986) and science teachers' intentions to use investigative teaching methods (Crawley, 1990).

Crawley and Koballa (1994) contend the work of Ajzen and Fishbein (1980) served as the catalyst for the momentum gained in persuasion research in the 1980s. Multiple studies using the theories of planned behavior and reasoned action significantly support both models' abilities to predict behavioral intentions and to provide a better understanding of the attitudinal and subjective normative correlates of specific behaviors (London, 1982). The theories of planned behavior and reasoned action provided guidance for constructing persuasive messages according to three conditions. First, changes in attitude, subjective norm, and perceived behavioral control will come about only when a sufficient number of the behavioral, normative, and control beliefs are changed. Second, changes in beliefs will affect behavioral intention only to the extent that attitude, subjective norm, and perceived behavioral control carry a significant weight in the prediction of intention. Third, the degree to which an intention change will cause a behavioral change is determined by the correspondence between intention and behavior.

Ajzen and Fishbein's Theory of Reasoned Action

Ajzen and Fishbein's theory of reasoned action (1980) formed the theoretical basis of this study. The theory of reasoned action (Figure 2) outlines a theoretical relationship between attitude and behavior. According to this theory, a person's behavior is assumed to be a function of his/her behavioral intention, which in turn is a function of attitudes toward the behavior and subjective norms regarding the behavior.

This formulation can be expressed algebraically by the following equation:

$B = BI = (Ab)\ W_1 + (SN)\ W_2$

where B = the behavior in question,

BI = behavior intention,

Ab = the attitude toward the behavior,

SN = subjective norm

W_1 and W_2 are empirically determined regression weights which are indicative of the importance of the attitudinal and normative components in predicting intentions.

The model's attitudinal and normative terms are further seen as a product of the person's beliefs. The attitudinal component (Ab) has consistently been shown to be highly related to an individual's beliefs that the behavior in question will lead to certain

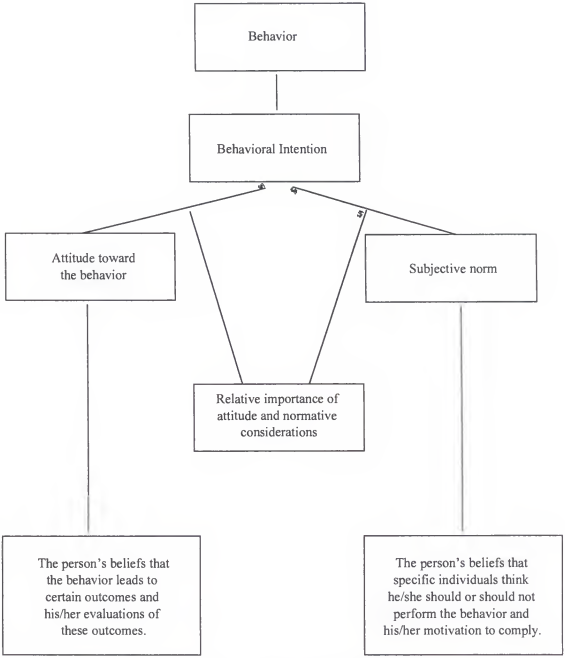

Behavior
Behavioral Intention
Attitude toward the behavior
Subjective norm
Relative importance of attitude and normative considerations
The person's beliefs that the behavior leads to certain outcomes and his/her evaluations of these outcomes.
The person's beliefs that specific individuals think he/she should or should not perform the behavior and his/her motivation to comply.

Figure 2. Factors determining a person's behavior (Ajzen and Fishbein, 1980).

consequences, weighted by his evaluations of those consequences. The hypothesized relationship between beliefs and attitudes may be expressed as follows:

$Ab = \sum Bi\ Ei$

where Ab = the attitude toward the behavior

Bi = the person's belief that the given act will lead to consequence i

Ei = the person's evaluations of consequence i

Similarly, the subjective norm component of the model (SN) has been shown to be related to the individual's normative beliefs about what significant others think he should do or should not do, weighted by his motivation to comply with others.

The hypothesized relationship between subjective norms and beliefs may be expressed as follows:

$SN = \sum NBi\ MCi$

where SN = subjective norm

NBi = the normative beliefs that a given other (referent i) thinks one should or should not perform the behavior

MCi = the person's motivation to comply with referent i

(Ajzen & Fishbein, 1980; Bowman & Fishbein, 1978).

Many researchers have used the theory of reasoned action to study the determinants of health-related behaviors. The following studies, as mentioned by London (1982), significantly support the model's ability to predict behavioral intentions and to provide a better understanding of the attitudinal and subjective normative correlates of specific behaviors. The major issues investigated in previous studies include alcohol use (Budd & Spencer, 1984; London, 1982; Roberts, Chval, & Dunlop, 1977; Schlegel, Crawford,

Sanborn, 1977), blood donation (Ahlering, 1979; Pomazal & Jaccard, 1976), cigarette smoking (Beck & Davis, 1980; Budd, 1986; Chassin, Presson, Sherman, Corty, Olshavsky, 1984; Dratt, 1986; Grube, Morgan, McGree, 1986; Hernandez-Ramos, 1985; Loken, 1982; Page, 1982; Peers & Christie, 1984; Presson, 1984; Sherman et al., 1982), consumer behavior (Fishbein & Ajzen, 1980; Ryan & Bonfield, 1975;), exercise (Godin, Colantonio, Davis, Shepard, and Simard, 1986; Godin & Shepard, 1984), family planning behaviors (Fishbein, Jaccard, Davidson, Ajzen, & Loken, 1980), health risk (O'Rourke, Smith, & Nottle, 1984), and premarital sexual intercourse (Ajzen & Fishbein, 1972, 1973).

A number of researchers have applied some form of the theory of reasoned action to understand the use of seat belts (Budd, Noth, & Spencer, 1984; Fhaner & Hane, 1974; Fishbein, Slazar, Rodriguez, Middelstadt, & Himmelfrab, 1988; Wittenbaker, Gibbs, & Kahle, 1983). Consistent with the theory, a person's intention to wear a seat belt is a good predictor of seat belt use (Wittenbraker et al., 1983). Intentions to wear seat belts can be predicted from a person's attitude toward wearing a seat belt and perceived social pressure to wear a seat belt (i.e., subjective norm) (Budd et al., 1984; Fishbein et al., 1988, Stasson & Fishbein, 1990).

It would seem logical that a person would consider the degree of perceived risk to his/her health and safety when deciding whether to perform behaviors that might endanger health or safety, but when it comes to wearing seat belts people do not assess perceived risk. A study by Stasson and Fishbein (1990) applied the theory of reasoned action to perceived driving risk and intentions to wear seat belts. They found in a given driving situation, appropriate measures of both attitudes and subjective norms had significant effects on one's intentions to wear a seat belt, but there was little direct relation between perceived driving risk and intentions. Perceived risk seemed to affect intentions indirectly through subjective norms and attitudes associated with seat belt use (Stasson & Fishbein, 1990).

Knapper et al. (1976) suggested that the Fishbein model may need to be amended when studying domains of behavior that are typically enacted by habit, as may be the case with wearing seat belts. Wittenbraker, Gibbs & Kahle (1983) state, "Although the Ajzen and Fishbein model is useful in predicting behavior that is largely under volitional control, the assumption that nontrivial behavior is under volitional control may not always be valid" (p. 408). With this idea in mind, Wittenbraker, Gibbs & Kahle (1983) proposed a more appropriate model for understanding seat belt usage that accounts not only for intention but also for habit. Thus, they amended the Ajzen & Fishbein model to include a habit component at the same level as intention:

Behavior = (W1) Intention + (W2) Habit

They propose just as intentions are multiply determined from attitudes and subjective norms, behavior may be multiply determined from habits and intentions. They surveyed 134 college students enrolled in an introductory psychology course. Their multiple regression analyses supported the Ajzen and Fishbein model predictions. Furthermore, habits were also shown to predict behavior in the regression analysis, supporting its addition to the theory of reasoned action.

There is a growing body of evidence to suggest that the relationship between intention and behavior is not as simple as Ajzen and Fishbein proposed (Bentler & Speckart, 1979; Saltzer, 1981; Manstead, 1983). Following Bentler and Speckart's study and recommendations, Budd, North, and Spencer (1983) adapted the Ajzen and Fishbein model to include a self-report measure of past behavior to improve the model's prediction of behavioral intention. They reported an increase of between seven and nine per cent to the model's predictive power. In addition, previous work has shown the attitudinal component is more important than the normative component in seat belt use (Budd et al., 1984).

Instructional Technology

In 1994, the Association for Educational Communications and Technology (AECT) defined instructional technology (IT) as "the theory and practice of design, development, utilization, management and evaluation of processes and resources for learning" (p. 2). Research on instructional films began around 1914 during the time of World War I and reached its peak in the mid 1950s (Thompson, Simpson & Hargrave, 1996). There are three major reviews of the research on instructional films: Hoban & Ormer's (1950) review of instructional film research 1918-1950; U.S. Army World War II studies on the use of films for training (Hovland, Lumsdaine, & Sheffield, 1949); and the 1967 Reid and MacLennan review. In 1996, the AECT produced a review (Thompson, Simpson & Hargrave, 1996) of instructional technology incorporating the findings from the earlier three major research reviews, as well as recent studies. They categorized their findings into three areas: (a) the effects of film on learning factual information, (b) the effects of film on higher cognitive skills, and (c) the relationship of film to learning styles.

The review reported the following uses and benefits of instructional film:

1. Films are an effective medium for conveying factual information that can be presented visually.

2. Various learner characteristics influence the acquisition of factual information.
3. Factual information gained through a film contributes more to a person's specific knowledge rather than general knowledge.
4. Film can facilitate improvement of students' abilities to attend to details and generate hypotheses in given problem situations.
5. Film can contribute to inquiry ability.
6. Instruction via film is more effective for students who are active and self-assured or students who are low in numerical and verbal aptitude.
7. Traditional instruction may work better than film instruction with passive, less responsible students with high numerical and verbal aptitudes.

From their review, Hoban and Ormer (1950) developed four guidelines that indicate an instructionally effective film:

1. Instruction instructional objectives should accompany an instructional film, the influence of a film is more specific than general.
2. To increase the influence of a film, the content of a film should be directly relevant to the response it is intended to evoke in viewers.
3. The influence of a motion picture is relatively unaffected by fancy production techniques.
4. Viewers respond to instructional films most efficiently when the visual content is presented from the perspective of the learner.

The teaching effectiveness of television has been well documented by over 40 years of research. Chu and Schramm (1967) summarized the research on instructional television and concluded:

> given favorable conditions, children learn efficiently from instructional television … the effectiveness of television has now been demonstrated in well over 100 experiments, and several hundred comparisons, … at every level from preschool through adult education and with a great variety of subject matters and method. (p.1)

The following is a list of characteristics and conditions of effective instructional television as complied by Chu and Schramm (1967) and Newman (1981):

1. Repeat key concepts in a variety of ways.
2. Make use of animation, novelty, variety, and simple visuals.
3. Entertain as well as inform.
4. Use a trained communicator (for adults: make use of nationally known personalities).
5. Provide opportunities for students to participate in a learning activity, either in response to information presented in a program or as part of a game presented by the program.
6. Match the length of the program to the attention span of the intended audience.
7. Follow the principles of effective audiovisual presentations.

Students show gains in achievement from viewing instructional television when teachers: (a) prepare students to receive information presented by the film; (b) provide reinforcing discussions and activities following viewing; (c) provide corrective feedback to students, based on what students reveal they have understood from the program, in follow-up discussions between students and teacher; (d) provide students with frequent feedback about their achievement as a result of viewing; and (e) assume an active role in the instruction that accompanies the viewing of television programs.

It has been estimated that 90% of the school districts in the nation use videotape equipment (Kelly & Hauseer, 1990). Reider (1985) determined the growth in the number of videotape players in schools has been greater than the rate of growth of microcomputers in schools. The effectiveness of instructional television has been substantiated by many studies (Thompson et al., 1996). White, Matthews, and Holmes (1989) reported that the use of videotapes to assist instruction can be significantly more effective in teaching students science concepts than conventional methods of instruction. As a delivery system, instructional television can present material in a manner that facilitates learning and can provide instruction that might not otherwise be available. Rudolph and Gardner (1986-87) reported that audio-graphic technology was as effective in delivering instruction about physics concepts as in-person presentations, as measured by posttest performance of high school students. Stice (1987) reported that college-level science students remember only 10% of what they read, 26% of what they hear, 30% of what they see, and 50% of what they see and hear. The science educational video and accompanying materials developed for this study applied the recommendations listed above (see Treatment section) and attempted to aid student recall of concepts (AECT, 1996; Chu and Schramm, 1967; Hoban and Ormer,1950; and Newman,1981).

Adolescent Safety Belt Use

Automobile collisions involving drivers between the ages of 16-19 have been a worldwide road safety and public health concern for decades (Mayhew & Simpson, 1996). In the United States, motor vehicle-related injuries are the greatest health problem for 16-19-year-olds and are responsible for more than one-third of all deaths in this age group (Williams, 1995). In addition, the crash rate for this age group is four times higher than all the other ages combined, 20 crashes per million miles driven compared with a rate of five crashes per million miles driven (National Highway Traffic Safety Administration, 1991; Research Triangle Institute, 1991). Within the 16-19 age group, the crash rate for 16-year-olds is the highest (43 crashes per million miles driven), followed by 17-year-olds (30 crashes per million miles driven).

The majority of European countries report a high proportion of young driver accidents with the exception of Ireland, where a higher proportion of youngsters are involved in motorcycle accidents. On average, the accident rate of 18-24 year olds in

Europe is about five times higher than the accident rates of the 25-65 year age group (Twisk, 1995). In Canada, road crashes are the leading cause of death among teens and account for one out of every eight deaths and injuries on their highways. Crash rates for Canada's teens exceed that of other age groups by a wide margin, with 34% of all teenage males and 38% of teenage females who die each year doing so as a result of a motor vehicle accident (Traffic Injury Research Foundation, 1999).

Despite strong evidence of the effectiveness of seat belts in substantially reducing the number of deaths and injuries resulting from automobile accidents (Fhaner & Hane, 1973; Grime, 1979; Hodson-Walker, 1970; Preston & Shortridge, 1973), their use is still fairly low among drivers in the United States, especially among young drivers (16-24 years old). A national observational survey of seat belt use conducted in 1994 indicated that 58 % of drivers (all ages and driving passenger cars) and right front passengers wore seat belts (NHTSA, 1995a). In addition to young drivers, groups with lower income and educational levels are less likely to wear seat belts than those of higher socioeconomic status (Lund, 1986; Mayas, Boyd, Collins, & Harris, 1983). Men are less likely than women to use seat belts. In a 1994 national survey by the National Highway Traffic Safety Administration, 54 % of men and 64 % of woman were using seat belts (NHTSA, 1995a).

Much of the data on rates of seat belt use by age has been obtained from observational surveys in which ages were estimated. However, observational surveys of students arriving at six high schools in Maryland and New York were conducted in 1982, 1988, and 1995. Williams, Wells, and Lund (1983) conducted the first observational study at and near six high schools in 1982 and reported safety belt use rates by high school students varied from 1% to 21% depending on the socioeconomic status of the areas in which the schools were located. Safety belt use rates for non-high school drivers from the same area around the high schools, driving in commuter traffic, ranged from 8% to 31%. Of the six schools surveyed, the lowest belt use rate was observed in the lowest socioeconomic district. The study was repeated in 1988 (Wells et al., 1989) and 1995 (Williams et al., 1997). One of the original six schools declined to participate and was replaced with another high school of similar size and socioeconomic status from the same county. There was substantial variation in seat belt use rates for the high school students (36 - 91 % for drivers, 24 - 74 % for passengers). In 1988, high school driver belt use was lower than among older comparison drivers and passengers who were observed commuting to work from the same residential area as the students driving to the high schools. This was again true in the 1995 study at three of the six schools for drivers, and four of the six schools for right front passengers. The wide variation in belt use rates largely reflects differences in socioeconomic status. The low belt use schools were located in census tracts with low 1990 median annual household income (school A: \$32,500; school B: \$30,094; school D; \$35,711). The schools with a high seat belt use rate were located in high median annual household income areas (\$72,781 for school E, \$74,167 for school F). School C, was in an area with a 1990 median household income of \$52,470 and had an intermediate belt use rate.

In a larger study conducted by the National Highway Traffic Safety Administration at intersections nationwide, the belt use rate for 16-24 years old (estimated) was 57 % for drivers and 50 % for right front passengers (NHSTA, 1995b). This lower seat belt use rate by young drivers is of concern because of their greater crash likelihood. In addition, the low rate of belt use by teenage passengers is particularly troubling, since passengers comprise about 40 % of all 16-19 year-old motor vehicle occupant deaths (Williams & Wells, 1995).

Roudebush (1985) utilized two attitude modification techniques in a high school driver's education course to find an effective means of improving students' attitudes toward safety belt usage. The first method of attitude modification was repeated exposure to safety belt information stimuli. Most of this information was delivered through lectures and incorporated whenever possible during the students' driver education course. The second method was three group discussion sessions aimed in a positive direction toward seat belt use. A Likert attitude scale pre-questionnaire and post-questionnaire were used to gather data. Roudebush (1985) found that if students wore seat belts as passengers before they could drive, they were more likely to wear seat belts after they received their driver's licenses. In addition, there was a strong relationship between parents' seat belt use and students' plans to use seat belts after they received their driver's licenses. An unusual finding of the Roudebush study was a negative trend in students' plans to use seat belts upon completion of their driver's education course. The study found that students suggested that their initial insecurity with learning to drive prompted their favorable attitude toward wearing seat belts. However, after having gained driving experience and confidence, they were less likely to wear seat belts.

Maron, Telch, Killen, Vranizan, Saylor, and Robinson (1986) examined the behavioral and psychosocial correlates of safety belt use of tenth graders in Northern California. Their 13-item questionnaire was designed to assess attitudes and behaviors regarding seat belt use of students, friends and family, especially parental use and influence. Incorporated in an 85-page questionnaire designed to detect risk factor behaviors related to coronary heart disease, the survey was administered over a five-day period. The researchers found Whites and Asians reported greater seat belt use than Blacks and other minorities, with Blacks reporting the lowest use of seat belts (46 % reported they never wore seat belts). Additionally, Maron et al. found that students reported they used seat belts more when they were with family members and that boys reported more frequent use than girls. Furthermore, Maron et al. found seat belt use by significant others as the strongest predictor of seat belt use. Parent educational levels, especially the fathers', were also positively associated with students' reported use of seat belts (Maron et al., 1986).

The Safety Impact of Driver Education and Training

Formal driver education can be traced to the turn of the century when the use of automobiles became a popular form of transportation. During the 1930s and 1940s, formal driver instruction experienced major growth as the field tried to establish a higher degree of professionalism and standardization. In the 1950s and 1960s, growth accelerated as research reported graduates of driver education courses had a lower frequency of collisions and violations than untrained individuals. However, the situation changed in the 1970s when the methodology and validity of the earlier studies was questioned, thereby challenging the beneficial effects of formal driver education. Consequently, the National Highway Traffic Safety Administration (NHTSA) launched a major driver education development and evaluation project in the late 1970s and early 1980s to evaluate the effectiveness of a comprehensive driver education program. Conducted in DeKalb County, Georgia, and involving approximately 16,000 students, the study still stands as the largest scale, well-designed and ambitious effort to assess the impact of formal driver instruction. The findings were disappointing. There was no convincing evidence that high school driver education reduces motor vehicle crash involvement rates for young drivers, either at the individual or community level (Vernick, Guohua, Ogaitis, MacKenzie, Baker, & Gielen, 1999). Results of the DeKalb study have been hotly debated and continually re-analyzed with ever-increasing sophisticated statistical procedures, yet the conclusions have been extremely consistent.

Other studies provided evidence that driver education courses were associated with a higher crash involvement rate for young drivers by providing an opportunity for early licensure (Robertson, 1980, Robertson & Zador, 1978; Vernick et al., 1999). In the early 1990s there was renewed interest in identifying ways to improve the safety impact of driver education. The impetus for this renewed interest was due in part to the success of multistaged graduated licensing systems introduced in New Zealand and the Canadian Provinces of Ontario and Nova Scotia. Both incorporated driver education as part of their systems. In a 1994 report to Congress, the National Highway Traffic Safety Administration (NHTSA, 1994) outlined their research agenda to develop an improved novice driver education program that would be integral to a graduated licensing system.

Given the large body of evidence that indicates formal driver education is ineffective at reducing crash rates in young drivers, this new interdependence between licensing and education has researchers and practitioners pressing for more studies to consider how the content and format of driver education programs might be altered to improve their effectiveness. In their report for The Traffic Injury Research Foundation of Canada, Mayhew and Simpson (1996) state, "One possible explanation for the failure of existing programs to produce bottom-line safety benefits is the curriculum fails to emphasize the knowledge and skills most critical to safe driving performance." (p. 69)

Of the various cognitive skills believed necessary for beginning drivers to acquire, research suggests only risk assessment and decision-making are critical to reducing the risk of collision (Mayhew & Simpson, 1996). Lonero, Clinton, Brock, Wilde, Laurie, and Black (1995) also included these skills in their study sponsored by the American Automobile Association (AAA) Foundation for Traffic Safety to develop a model curriculum outline for novice driver education. Based on a review of the literature and a survey of experts, the curriculum focused not only on driver skill but also intensely on the knowledge, attitudes, and motivational factors of young drivers. Under the knowledge context, Lonero et al. identified "Physics of Driving" as key subject matter in driver education.

Other experts have underscored the importance of knowledge and motivation. McKnight (1985) was the first to argue for a resequencing of instruction to allow for better integration of important content knowledge with student experience gained in real world driving (i.e., following initial licensing in a graduated licensing program). More recently, NHTSA has recommended a two-stage driver education program (NHTSA, 1994): a basic driver education course in the learner stage and an advanced driver education course in the intermediate stage. They propose that instruction in decison-making topics (i.e., relationships between vehicle speed, braking, friction, and mass) would be more meaningful and, therefore, effective if introduced after the novice driver has obtained behind-the-wheel experience.

In addition to changing *what* is taught to novice drivers, many call for a change in *how* it is taught. Mayhew and Simpson (1996) first proposed that, "teaching methods and techniques should be developed to address lifestyle and psychosocial factors that can mitigate any beneficial effects of training and lead to risky driving behaviors" and second, that "the curriculum should include experiences that demonstrate the value of safety practices and thereby motivate novices to drive safely" (p. 81). The Insurance Bureau of Canada sponsored an international symposium entitled "New to the Road: Prevention Measures for Young or Novice Drivers" and published (1991) a report under the same title. Key findings and implications included these two:

1. "There is a need to examine critically both the existing methods and systems of delivery for driver education and training." (p. 37)
2. "The enhancement of effective programs such as seat belt use must continue and the development and implementation of new initiatives such as early education programs encouraged." (p. 39).

Summary

This review of literature has described the educational pedagogy, research theory, and driver education reform efforts which support the theory that an educational science video and accompanying hands-on science activities will have a positive effect on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts.

When the inadequacies of our educational system are viewed from the perspective of vehicle crashes and deaths involving young drivers, a new emphasis for driver's education efforts in school reform becomes critical. Linking driver education with graduated licensing is emerging as a reform model with the potential for lowering young drivers' crash rates. But how can the efficacy of this education-based reform effort be increased? The National Highway Traffic Safety Administration and the American

Automotive Association Foundation for Traffic Safety believe the answer lies in a complete overhaul of the driver education curriculum and delivery system. They urge continued research to examine new opportunities for driver education as a means of preventing collisions involving young motorists (Simpson, 1996).

The following chapters outline precisely that–research on a new opportunity to reduce or prevent young adult injuries and fatalities in vehicle collisions. No other study has been completed that includes all of the features of this research and that addresses the important area of driver education by involving a fundamental shift in pedagogy toward proven science education methods to change students' knowledge, attitudes and intended behaviors relating to traffic safety.

CHAPTER 3
RESEARCH DESIGN AND IMPLEMENTATION

Introduction

The purpose of this chapter is to describe the design and methodology of the study. The purpose is to investigate the effects of a curricular program utilizing a science education practice of integrating video-based instruction with accompanying activity-based instruction on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts. Quantitative methods were used to document the changes that occurred in students as a result of exposure to the treatments. The investigation used a split plot, repeated measures quasi-experimental design. Secondarily, order effects and interactions between treatments were investigated.

It was hypothesized that a curricular program utilizing a science education practice of integrating video-based instruction with accompanying activity-based instruction would have a positive impact on students' use of seat belts.

All participants were given identical assessments on three occasions. A pre-assessment survey was given to determine students' past behavior related to seat belt use. The main instrument was divided into three sections. Each section measured one of the following constructs: (a) knowledge regarding the physics of car crashes relating to seat belt use, (b) attitudes regarding seat belt use, and (c) behavioral intentions regarding seat belt use. The instrument was given as the pretest at the beginning of each session and as a posttest after each treatment (Part One after Treatment A, Part Two after Treatment B).

Group A experienced video-based instruction (Treatment A), completed posttest Part One, received activity-based instruction (Treatment B), and then completed posttest Part Two. Group B received activity-based instruction (Treatment B), completed posttest Part One, experienced video-based instruction (Treatment A), and then completed posttest Part Two. Both groups received video-based instruction and activity-based instruction (Treatments A-B and B-A). Both of the control groups continued the normal curriculum planned by their teachers during the two-week study period covering general biology and chemistry concept lessons, but without viewing the video and participating in physics of car collisions activities.

Research Questions

The following research questions were addressed in this study:

1. What are the effects of Treatment A (exposure to video-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?
2. What are the effects of Treatment B (activity-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?
3. What are the effects of varying the sequence of presentation of Treatments A and B on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?

Research Hypotheses

The following null hypotheses were tested:

1. After participating in video-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.
2. After participating in video-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.
3. After participating in video-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.

4. After participating in activity-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.
5. After participating in activity-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.
6. After participating in activity-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.
7. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.
8. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in attitudes regarding seat belt use.
9. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in behavioral intentions regarding seat belt use.
10. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater knowledge gains regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.
11. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive changes in attitudes regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.
12. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive shifts in behavioral intentions regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

Description of Setting

The setting for the study was a high school located in a medium-sized city in north central Florida. The school is unique in that it is a developmental research school (or laboratory school) and provides facilities for students in grades Kindergarten through 12. The total enrollment for all grade levels is approximately 1100 students. Data were collected on 194 of the 254 students enrolled in high school biology and chemistry classes over a 10-day period. The instruments were not administered to 60 students because of their absence from school on the days the teachers administered the instruments, their involvement in school activities that prevented them from being in class, or other valid reasons.

Description of Participants

The study sample consisted of all students enrolled in high school biology and chemistry classes (ages 15-17 years old) in the school described. The demographics of the students enrolled at the school are representative of the state's characteristics in terms of gender, ethnicity, and socioeconomic status. This representation is accomplished by having students on a lottery system for each category and selecting students from the system as slots open in a category. By filling the slots with students whose characteristics fit the needs of the school, the representative sample of the population can be maintained. Socioeconomic status is based on the student's family total income for the previous 12 months. Students are placed in one of four categories based on their family's reported and verifiable annual income: category #1, $0 - $17,499 (12% of study group); category #2, $17,500 - $32, 499 (22% of study group); category #3, $32, 500 - 52, 499 (26% of study group), and category #4, $52, 500 or greater (40% of study group).

Experimental Research Design

A quasi-experimental, pretest/posttest, nonequivalent group design was used because it was unfeasible to randomly assign students to treatment or control groups for this study (Cook & Campbell, 1979). A split plot, repeated measures quasi-experimental design provided quantitative data that was used to answer questions about possible relationships between video-based science instruction and accompanying hands-on science activities on high school students' knowledge, attitudes, and behavioral intentions related to seat belt use. This experimental design helped to answer questions about the effects of a single treatment and cumulative effects of multiple treatments. The split-plot repeated measures quasi-experimental design was selected for the increased power it offered through multiple measures on the same individuals.

Various assumptions are made when using the split plot design. The randomized-blocks analysis of variance (RBANOVA) test is fairly robust to the normality assumption and need not be addressed. The test's independence is not robust and procedures were established to ensure independence of the measures. The use of proctors and directions read aloud that asked the participants to do their own work helped reduce or eliminate the threat to validity caused by error effects that are not independently determined and distributed. Bonferroni's correction procedure was used as a follow-up test to identify effects on posttest means due to each intervention. Table 3-1 provides the experimental design for the study.

Sampling Procedure

Students could not be randomly assigned for the investigation; thus intact classes were used for cluster random sampling. Demographic information regarding the students' gender, grade level, race/ethnicity, and socioeconomic status was collected from students' school files. The anonymity of the students was assured by having a data collection number assigned to each student.

Table 3-1. Experimental Design of the Study

Outcomes	Chemistry Classes (5) Group A	Biology Classes (5) Group B
knowledge	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 O3	O1 O3
attitudes	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 O3	O1 O3
behavioral intentions	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 X1 O2 X2 O3	O1 X2 O2 X1 O3
	O1 O3	O1 O3

O1 – Pretest
O2 - Posttest 1
O3 - Posttest 2
X1 - exposure to video-based instruction (Treatment A)
X2 - exposure to activity-based instruction (Treatment B)

Instrumentation

Each student in the investigation completed two types of researcher designed tests (see Appendix A): a 50-item pre-assessment survey (see Appendix A-1) and a 43-item main instrument (see Appendix A-2). The pre-assessment survey was administered only once to measure past behavior relating to seat belt use. The main instrument was used for the pretest, posttest 1 and posttest 2 to ensure equivalence of forms for a given session. The main instrument was divided into three sections with each section measuring one of the following constructs: 1) knowledge regarding the physics of car crashes relating to seat belt use, 2) attitudes regarding seat belt use, and 3) behavioral intentions regarding seat belt use. The majority of the pre-assessment survey questions were modified from a large-scale study conducted by the U. S. Department of Transportation in 1996.

The knowledge questions of the main instrument were written by the researcher and the remaining attitudinal and behavioral intention questions were adapted from the Insurance Institute for Highway Safety's New Car Safety Survey (1996) and safety belt questionnaires utilized by Mori (1988), and Werch (1988). In order to assess the reliability of the instrument, a pilot study was conducted in the spring of 2001-2002 school year with a convenience sample, consisting of two intact classes of 41 9th and 10th-grade students not participating in the research study. Cronbach's coefficient alpha was used to compute test score reliability for each construct of the instrument (knowledge, attitude, and behavioral intentions). The knowledge, attitude, and behavioral intention instrument scores for internal consistency were .19, .76, .95, respectively. The low reliability score of the knowledge instrument as a whole was attributed to high item difficulty and a low number of items. Since the reliability coefficient of the knowledge instrument overall was too low to use as a holistic measure, pre and posttest scores for each knowledge item were analyzed individually.

Content validity of the instrument's knowledge questions was determined by sending copies of the instrument to three experts for review. A physics professor, a professor of science education, and a high school science teacher each completed a

Science Content Validity Evaluation Form (see Appendix B-1) to rate science content accuracy and completeness. Each expert determined the science content of the knowledge questions was accurate and complete. An expert in the field of traffic safety evaluated the content validity of the attitude and behavioral intention questions. Suggestions were given for restructuring of three questions, one to include responses for different driving scenarios and two to change the responses to be answered in the negative.

Instructional validity is the match between content covered in the lessons and the content covered on the tests (Crocker & Algina, 1986). A Table of Specifications was used to assess instructional validity (see Appendix C). The table compared the number and percent of activities covering specific content areas with the number and percent of questions on the test in the same content areas. The close match between the number of lessons on each content topic and the percent of the assessment instrument addressing these same topics is an indication of instructional validity.

Treatment

The treatment was defined as the presentation of video-based instruction (Treatment A) or hands-on activity-based instruction (Treatment B).

Treatment A. Treatment A was defined as participating in a 50-minute video-based instructional activity. The lesson was teacher-directed using one 22-minute videotape on the physics of automobile collisions and two accompanying video question sheets.

The Insurance Institute for Highway Safety (IIHS)--a nonprofit research and communications organization dedicated to reducing highway crash deaths, injuries, and property losses--produced the video. Working with the IIHS staff, the researcher acted as lead writer and on-camera host, to create a documentary style short film on the physics of car crashes to be used in high school introductory science classes. As part of the effort to reduce teen driving deaths, the video had the following three primary objectives: 1) to supplement high school science curricula with an interesting film that demonstrated basic principles of physics and related them to modern crashworthiness of automobiles, 2) to impress upon students the magnitude of forces resulting from high-speed crashes and the roles of vehicle mass, speed, and vehicle safety-features in determining crash forces, and 3) to facilitate an understanding of the importance of seat belts and stimulate an increase in their use.

The pedagogical format of the video was determined by the researcher and based upon a summary of instructional television research by Chu and Schramm (1967) and Newman (1981). The following six major findings from the research were implemented in the video's production: a) repeat key concepts in a variety of ways (video used simple demonstrations, visual analogies, formulas, and dramatic car crashes); b) make use of animation, novelty, variety, and simple visuals (video utilized animated crash sequences, novel camera angles, quick visual pace, and screen overlays of formulas); c) entertain as well as inform (script incorporated visual humor using crash-test dummies); d) make use of a trained communicator (researcher, with 15 years high school teaching experience, was on-camera host for the video); e) provide opportunities for students to participate in a learning activity, either in response to information presented in a program or as part of a game presented by the program (lesson plans for hands-on science activities provided with video); f) match the length of the program to the attention span of the intended audience (length of video relatively short at 22 minutes).

Two physics professors with an interest in instruction and curriculum issues and one high school physics instructor with a graduate degree in physics reviewed the video's script for content validity. Each script (see Appendix D) included summaries of on-camera visuals, narrative voice-overs by the researcher, time indicators, and dialog from an on-camera discussion between the researcher and an expert on the crashworthiness of vehicles. All three experts have a keen interest in physics education and have experience in car crash-related physics curricula. Each expert's review supported the content and organization of the video.

To ensure the content validity of the final video production, preview copies of the video were sent to the original three script reviewers and five additional experts. A professor of science education, two high school physics teachers with graduate degrees in science education, and a science program specialist from a state department of education evaluated the education content. An additional physics professor reviewed the science content of the preview video. Again, each expert's review supported the content and organization of the video. The video was also pilot tested with high school students by six of the reviewers. Three suburban, middle-income high schools in Virginia, two rural, low-income high schools in Florida, and one urban, high-income private school in California participated in pilot testing the video. Comments and suggestions from the students were recorded by the classroom teacher and mailed to the Insurance Institute for Highway Safety. Many of their suggestions for improving the graphic overlays and pacing were incorporated in the final editing of the video.

The accompanying video question sheets were crucial elements to Treatment A (see Appendix E). Created by the researcher, the video question sheets were designed to help participants better understand the physics concepts presented in the video. Based on the summary of instructional television research by Chu and Schramm (1967) and Newman (1981), the content and pedagogical format of the video question sheets addressed the following five research-based recommendations for increasing student achievement when viewing instructional television: a) prepare students to receive information presented by the film; b) provide reinforcing discussions and activities following viewing; c) provide corrective feedback to students, based on what students reveal they have understood from the program, in follow-up discussions between students and teacher; d) provide students with frequent feedback about their achievement as a result of viewing; e) assume an active role in the instruction that accompanies the viewing of television programs.

The first video question sheet was an advance organizer of the content presented in the video (see Appendix E-1). It prepared participants to receive information presented in the film by providing a variety of lower-order questions (i.e., fill-in-the-blank or circle-the-correct-answer statements) taken from the dialogue of the video. A column indicating the time the statement was heard in the video was aligned with the statements. Participants completed 40 lower-order questions as they watched the video. Teachers were instructed to stop the video periodically for students to collaborate on the answers, provide corrective feedback, and reinforce key concepts. Once completed, the sheet was used in follow-up discussions between participants and teachers or as a study guide for later assessments. The second video question sheet was a post-video sheet of eight higher-order, short-essay questions intended to stimulate reinforcing discussions and activities among participants and teachers (see Appendix E-2).

Three science education experts reviewed the video question sheets for content validity. A professor of science education, a high school physics teacher with a graduate degree in science education, and an author of a high school physics textbook evaluated the education content and format of the video question sheets. Each expert's review supported the education content and format of the video question sheets.

Treatment B Treatment B was defined as participation in four hands-on science activities about car crash-related physics concepts selected and written by the researcher (see Appendix E-3). The lessons introduced students to the physics of car crashes with high-interest, grade-level appropriate activities designed to meet National Science Education Content Standards (National Research Council, 1996). Since research has shown that students show gains in achievement from viewing instructional television when teachers provide reinforcing discussions and activities following viewing (Chu and Schramm, 1967; Newman, 1981) complete teacher lesson plans and blackline masters of activity sheets were developed by the researcher for each activity. Each lesson was organized using the same standard format, including the following 11 components:

1. Key Question(s) -- stated the primary focus of the activity in the form of a question that was relevant to students' experience. Key questions were used to initiate or conclude the activity.
2. Grade Level -- suggested appropriate grade levels.
3. Time required to complete lesson -- estimated the range of time needed to complete the main procedure of the lesson with a class size of 28-32 students. Additional time was necessary to complete "Going Further" activities.
4. National Science Education Standards -- activities were correlated to Content Standards: Grades 9-12 of the National Science Education Standards, National Academy of Sciences, Washington D.C., 1996.
5. Behavioral objectives -- identified desired student outcomes in the form of observable behaviors.

6. Background information -- contained relevant background information on the science concepts explored in the activity. Key concepts and vocabulary were in bold face type.
7. Crash course definitions -- listed and defined key science vocabulary used in the lesson.
8. Materials -- listed all supplies needed for students working in small groups to complete the activity.
9. Getting ready -- described steps the teacher should take to prepare for the activity.
10. Procedure -- included step-by-step instructions for completion of the lesson. The procedure followed the three-stage learning cycle of exploration, concept development, and application. Answers to the student activity sheet questions were provided.
11. Extension(s) -- suggested additional activities to reinforce lesson objectives and introduced related concepts.

Content validity of the hands-on science activities was determined by sending copies of each of activity to seven reviewers. The experimenter provided each reviewer with either a science content validity form or a pedagogical validity form depending on the reviewer's area of expertise (see Appendix B).

The science content reviewers for the hands-on science activities were two physics professors, an engineer in the automobile safety industry, and a high school physics teacher. Each expert completed a Content Validity Evaluation Form (see Appendix B-2) for each of the hands-on science activities. The reviewers were asked to rate science content accuracy and completeness. One reviewer rated all six hands-on lessons as accurate and complete. The other three reviewers rated four of the six lessons as complete and accurate but each noted the same lesson as redundant. One reviewer commented a proposed lesson on measuring reaction time and relating it to crash avoidance might lead some participants to believe their quick reaction time justifies their unsafe driving behavior. The content reviewers' concerns were addressed by reducing the number of hands-on activities from six to four.

Three education experts reviewed the hands-on science activities and completed a Content Validity Evaluation Form (see Appendix B-3) to rate pedagogical validity. A professor of science education, one national-board certified high school science teacher, and an author of a high school physics textbook reviewed the education content and format of the lessons. The reviewers were asked to evaluate the pedagogical validity by determining if the content was age-appropriate and sufficiently covered. The raters also scored the lessons by looking for key lesson elements such as clear objectives, precise directions, accurate time estimates, and appropriate material selection. Each rater scored 100% of the lessons as appropriate for the purposes of the study. Two reviewers commented on the redundancy of one of the lessons. The remaining reviewer commented that the lessons could easily be simplified or extended for varying age or ability levels. Appendix E contains a complete set of the teacher lesson plans and student activity sheets.

Teacher Training

Each of the treatment group teachers received a complete curriculum package (see Appendix E) that included a schedule of the study's activities with estimated time requirements, a list of the lessons and corresponding physics concepts covered, and a curriculum guide of objectives. The treatment group teachers received three hours of initial training from the researcher. The major points of the study were covered, including summaries on the history of driver's education, vehicle occupant safety research (i.e., seat belts, airbags, and head restraints), and vehicle crashworthiness research (i.e., safety cage intrusion data and crash-test dummy data).

The researcher discussed the major concepts of each lesson and the expected outcomes for each lesson. After the lessons were discussed, the researcher modeled the various lesson instruction techniques for the teachers. Both of the treatment group teachers worked through the lessons with the researcher in an effort to ensure uniformity of instructional methods. By having the treatment group teachers participate in the lessons as students, the researcher's intent was to build a uniform instructional methods base for the treatment group teachers.

It is acknowledged that there were differences in the individual teaching methods because of teachers' personalities, but the training instruction methods were included to provide a single model (as exemplified by the researcher) for the teachers to follow as they conducted the lessons. The researcher was available for consultation throughout the study.

CHAPTER 4
RESULTS

The purpose of this study was to examine the effects of a curricular program utilizing a science education practice of integrating video-based instruction with accompanying activity-based instruction on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts. Secondarily, the purpose was to determine order effects and interactions between the two treatments used in the study: video-based instruction and hands-on activity-based instruction. The study used Ajzen and Fishbein's (1980) theory of reasoned action to investigate the factors influencing high school students' behavioral intentions regarding seat belt use.

Ten intact high school science classes (eight treatment and two control) took pretests and posttests measuring physics knowledge, attitudes, and behavioral intentions toward seat belt use prior to and after participating in the two treatments.

Treatments consisted of a video-based instruction and hands-on activity-based instruction for a total of approximately 500 minutes over 10 instructional days. Treatment A was defined as participating in one 50-minute video-based instructional lesson. The lesson was teacher-directed using one 22-minute videotape on the physics of automobile collisions and two accompanying video question sheets. Treatment B was defined as participating in four hands-on science activities about car crash-related physics concepts. The lessons introduced students to the physics of car crashes with high-interest, grade-level appropriate activities designed to meet National Science Education Standards (1996).

Four of the classes participating in the study completed the video lessons first and the hands-on science activities second (Group A), and the other four classes completed the hands-on science activities first and the video lessons second (Group B). As indicated in Table 4-1, a total of 66 students were in Group A and 91 students were in Group B.

Table 4-1. Number of Participants for Each Treatment Group

Class Period	Group A (Number)	Group B (Number)
1	21	16
2	13	28
3	13	27
4	19	20
Total	66	91

Each participant in the study completed two researcher-designed assessments: a 50-item pre-assessment survey and a 43-item main instrument. The pre-assessment survey was administered only once to measure past behavior relating to seat belt use. The main instrument was used as the pretest, posttest 1 and posttest 2 to ensure equivalence of forms for a given session. The main instrument was divided into three sections with each section measuring one of the following constructs: (a) knowledge regarding the physics of car crashes relating to seat belt use, (b) attitudes regarding seat belt use, and (c) behavioral intentions regarding seat belt use. Analyses measured the effects of the treatments on students' knowledge, attitudes, and behavioral intentions toward seat belt use. Additional analyses examined order effects and interactions between the two treatments used in the study. The results of these analyses are presented in the following sections.

The results for the following research questions are presented in this chapter:

1. What are the effects of Treatment A (video-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?
2. What are the effects of Treatment B (activity-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?
3. What are the effects of varying the sequence of presentation of Treatments A and B on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?

Video-Based Instruction Effects

Student knowledge regarding the physics of car crashes relating to seat belt use was measured using 12 multiple-choice questions on the pretest, posttest one, and posttest two (see Appendix A-2). Table 4-2 provides the pretest and posttest 1 knowledge test means and standard deviations for Group A.

A general linear model procedure was used to conduct a repeated measures analysis of variance to test the following hypotheses:

Hypothesis 1: After participating in video-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

Table 4-2. Mean Scores and Standard Deviations for Knowledge Items 1-12,Group A, Pretest - Posttest 1 of Treatment A

		Group A	
Item Number	Source	M	SD
1	Pretest	.4394	.5001
	Posttest 1	.9242	.2666
2	Pretest	.9090	.2897
	Posttest 1	1.000	0
3	Pretest	.5151	.5036
	Posttest 1	.9090	.2897
4	Pretest	.4697	.5029
	Posttest 1	.6061	.4924
5	Pretest	.3788	.4888
	Posttest 1	1.000	0
6	Pretest	.9242	.2666
	Posttest 1	.8485	.3613
7	Pretest	.1667	.3755
	Posttest 1	.5606	.5001
8	Pretest	.1212	.3289
	Posttest 1	.6970	.4631
9	Pretest	.9848	.1230
	Posttest 1	.9394	.2404
10	Pretest	.3485	.4801
	Posttest 1	.6818	.4693
11	Pretest	.3787	.4889
	Posttest 1	.7879	.4119
12	Pretest	.7576	.4318
	Posttest 1	.7727	.4223

Note: Treatment A = video-based instruction

To test this hypothesis, pretest scores and posttest 1 scores of students in Group A were compared. Posttest 1 was administered after completion of Treatment A (exposure to video-based instruction) but before implementation of Treatment B (activity-based instruction). As shown in Table 4-3, results of the repeated measures analysis of variance indicated significant differences between the pretest and posttest 1 means for Group A for 9 of the 12 knowledge questions. A Bonferroni correction was employed for the 12 ANOVAs by dividing the preset overall 0.05 significance level by the number of items (12) resulting in a significance level of .004167. The null hypothesis was rejected since exposure to video-based instruction significantly improved knowledge regarding the physics of car crashes on 75% of the knowledge test items.

Table 4-3. Source Table for Repeated Measures Analysis of Variance for Knowledge Items 1-12, Group A, Pretest and Posttest 1 for Treatment A

Item Number	F	P
1	54.22	.0001*
2	7.87	.0006*
3	31.54	.0001*
4	13.59	.0001*
5	110.27	.0001*
6	.59	.5580
7	96.32	.0001*
8	101.79	.0001*
9	.49	.6132
10	10.41	.0001*
11	29.99	.0001*
12	1.18	.3108

Significant at the .004167 level.
Note: Treatment A = video-based instruction

Student attitudes toward seat belt use were measured using 10 questions with Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use (see Appendix A-2).

Hypothesis 2: After participating in video-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.

To test this hypothesis, pretest scores and posttest 1 scores of students in Group A were compared. Posttest 1 was administered after completion of Treatment A (exposure to video-based instruction) but before implementation of Treatment B (activity-based instruction). Table 4-4 provides the pretest and posttest 1 attitude assessment means for Group A (video-based instruction). As shown in Table 4-5, the results of the repeated measures analysis of variance indicated significant differences between pretest and posttest 1 attitude scores (alpha = 0.05). The null hypothesis was rejected since video-based instruction resulted in significantly positive changes in attitudes regarding seat belt use.

Table 4-4. Mean Scores and Standard Deviations for Attitudes, Group A, Pretest – Posttest 1 for Treatment A

Source	Test	M	SD
Group A	Pretest	14.07	4.390
	Posttest 1	13.13	3.706

Table 4-5. Source Table for Repeated Measures Analysis of Variance of Attitudes, Group A, Pretest – Posttest 1 for Treatment A

Source		SS	df	MS	F	P
Group A	S	30.61	1	30.61	5.524	.022*
	Error	376.9	68	5.542		

Significant at the 0.05 level.

Student behavioral intentions toward seat belt use were measured using 20 questions. Three of the questions used Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use. The remaining 17 questions required the students to check items that described situations where they were more likely to wear a seat belt (see Appendix A-2).

Hypothesis 3: After participating in video-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.

To test this hypothesis, pretest scores and posttest 1 scores of students in Group A were compared. Posttest 1 was administered after completion of Treatment A (exposure to video-based instruction) but before implementation of Treatment B (activity-based instruction). Table 4-6 provides the pretest and posttest 1 behavioral intention means for Group A (video-based instruction). As shown in Table 4-7, the results of the repeated measures analysis of variance for the Likert-scale questions indicated significant differences between pretest and posttest 1 scores (alpha level 0.05). Analysis of the longer 17-item checklist indicated there was a significant difference between Group A's pretest and posttest 1 scores (see Table 4-8). The null hypothesis was rejected since video-based instruction resulted in significantly positive changes in behavioral intentions regarding seat belt use.

Table 4-6. Mean Scores and Standard Deviations of Behavioral Intentions, Group A, Pretest – Posttest 1 for Treatment A

		Likert-Type Items		17-Item Checklist	
Source	Test	M	SD	M	SD
Treatment A	Pretest	5.725	2.905	12.22	4.277
	Posttest 1	4.884	2.435	14.06	3.895

Note: Treatment A = video-based instruction

Table 4-7. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, Likert-scale Items, Group A, Pretest – Posttest 1 for Treatment A

Source		SS	df	MS	F	P
Treatment A	S	24.378	1	24.38	18.09	.000*
	Error	68	68	1.347		

Significant at the 0.05 level.
Note: Treatment A = video-based instruction

Table 4-8. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, 17-Item Checklist, Group A, Pretest – Posttest 1 for Treatment A

Source		SS	df	MS	F	P
Treatment A	S	116.9	1	116.9	22.10	.000*
	Error	359.6	68	5.289		

* Significant at the 0.05 level.
Note: Treatment A = video-based instruction

Activity-Based Instruction Effects

Student knowledge regarding the physics of car crashes relating to seat belt use was measured using 12 multiple-choice questions on the pretest, posttest one, and posttest two (see Appendix A-2). Table 4-9 provides the pretest and posttest 1 knowledge test means and standard deviations for Group B.

Hypothesis 4: After participating in activity-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

To test this hypothesis, pretest scores and posttest 1 scores of students in Group B were compared. Posttest 1 was administered after completion of Treatment B (exposure to hands-on activity-based instruction) but before implementation of Treatment A (exposure to video-based instruction). As shown in Table 4-10, results of the repeated measures analysis of variance indicated significant differences between the pretest and posttest 1 means for Group B for 9 of the 12 knowledge questions. A Bonferroni correction was employed for the 12 ANOVAs by dividing the preset overall 0.05 significance level by the number of items (12) resulting in a significance level of .004167. The null hypothesis was rejected since exposure to activity-based instruction significantly improved regarding the physics of car crashes on 75% of the knowledge test items.

Table 4-9. Mean Scores and Standard Deviations for Knowledge Items 1-12, Group B, Pretest – Posttest 1 for Treatment B

		Group B	
Item Number	Source	M	SD
1	Pretest	.4505	.5003
	Posttest 1	.8461	.3628
2	Pretest	.8681	.3402
	Posttest 1	.9890	.1045
3	Pretest	.4396	.4991
	Posttest 1	.6813	.4685
4	Pretest	.3187	.4689
	Posttest 1	.6923	.4641
5	Pretest	.3956	.4917
	Posttest 1	.8901	.3145
6	Pretest	.9121	.2847
	Posttest 1	.9341	.2495
7	Pretest	.0440	.2061
	Posttest 1	.3516	.4801
8	Pretest	.0330	.1795
	Posttest 1	.3516	.4801
9	Pretest	.9341	.2495
	Posttest 1	1.000	0
10	Pretest	.2857	.4543
	Posttest 1	.2747	.4488
11	Pretest	.2637	.4431
	Posttest 1	.4945	.5027
12	Pretest	.7692	.4237
	Posttest 1	.8462	.3628

Note: Treatment B = activity-based instruction

Table 4-10. Source Table for the Repeated Measures Analysis for Knowledge Items 1-12, Group B, Pretest and Posttest 1 for Treatment B

Item Number	F	P
1	54.22	.0001*
2	7.87	.0006*
3	31.54	.0001*
4	13.59	.0001*
5	110.27	.0001*
6	.59	.5580
7	96.32	.0001*
8	101.79	.0001*
9	.49	.6132
10	10.41	.0001*
11	29.99	.0001*
12	1.18	.3108

* Significant at the .004167 level
Note: Treatment B = activity-based instruction

Student attitudes toward seat belt use were measured using 10 questions with Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use (see Appendix A-2).

Hypothesis 5: After participating in activity-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.

To test this hypothesis, pretest scores and posttest 1 scores of students in Group B were compared. Posttest 1 was administered after completion of Treatment B (activity-based instruction) but before implementation of Treatment A (video-based instruction). Table 4-11 provides the pretest and posttest 1 attitude assessment means for Group B (activity-based instruction). As shown in Table 4-12, the results of the repeated measures analysis of variance indicated no significant differences between pretest and posttest 1 attitude scores (alpha = 0.05). The null hypothesis was not rejected since activity-based instruction did not result in significantly positive changes in attitudes regarding seat belt use.

Table 4-11. Mean Scores and Standard Deviations for Attitudes, Group B, Pretest – Posttest 1 for Treatment B

Source	Test	M	SD
Treatment B	Pretest	16.10	4.660
	Posttest 1	16.10	6.146

Note: Treatment B = activity-based instruction

Table 4-12. Source Table for Repeated Measures Analysis of Variance of Attitudes, Group B, Pretest – Posttest 1 for Treatment B

Source		SS	df	MS	F	P
Treatment B	S	.000	1	.000	.000	1.000
	Error	1580	95	16.63		

Note: Treatment B = activity-based instruction

Student behavioral intentions toward seat belt use were measured using 20 questions. Three of the questions used Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use. The remaining 17 questions required the students to check items that described situations where they were more likely to wear a seat belt (see Appendix A-2).

Hypothesis 6: After participating in activity-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.

Table 4-13 provides the pretest and Posttest 1 means for Treatment B (activity-based instruction) regarding their behavioral intentions toward seat belt use. As shown in

Table 4-14 the results of the repeated measures analysis of variance indicated significant differences between pretest and Posttest 1 means (alpha level 0.05) on the Likert-scale questions indicating an effect due the activity-based instruction.

Table 4-13 provides the pretest and posttest 1 behavioral intention means for Group B (activity-based instruction). As shown in Table 4-14, the results of the repeated measures analysis of variance for the Likert-scale questions indicated significant differences between pretest and posttest 1 scores (alpha level 0.05). Yet analysis of the longer 17-item checklist indicated there was no significant difference between Group B's pretest and posttest 1 scores (see Table 4-15). Due to the higher reliability score of the checklist section of the assessment, the researcher decided not to reject the null hypothesis. The null hypothesis was not rejected since activity-based instruction did not result in significantly positive changes in behavioral intentions regarding seat belt use.

Table 4-13. Mean Scores and Standard Deviations of Behavioral Intentions, Group B, Pretest – Posttest 1 for Treatment B

		Likert-Type Items		17 Item Checklist	
Source	Test	M	SD	M	SD
Treatment B	Pretest	6.240	2.603	11.99	4.466
	Posttest 1	5.563	2.302	12.41	4.900

Table 4-14. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, Likert-scale Items, Group B, Pretest – Posttest 1 for Treatment B

Source		SS	df	MS	F	P
Treatment B	S	22.01	1	22.01	12.87	.001*
	Error	162.5	95			

Significant at the 0.05 level.

Table 4-15. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, 17-Item Checklist Group B, Pretest – Posttest 1 for Treatment B

Source		SS	df	MS	F	P
Treatment B	S	8.755	1	8.755	2.118	.149
	Error	392.7	95			

Combined Treatment Effects

Four of the classes participating in the study completed the video lessons first and the hands-on science activities second (Group A), and the other four classes completed the hands-on science activities first and the video lessons second (Group B). Student knowledge regarding the physics of car crashes relating to seat belt use was measured using 12 multiple-choice questions on the pretest and posttest two (see Appendix A-2). Table 4-16 provides the pretest and posttest 2 knowledge test means and standard deviations for Group A.

Hypothesis 7: The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

To test this hypothesis, pretest scores and posttest 2 scores of students in Group A were compared. Posttest 2 was administered after completing the combined treatment of presenting video-based instruction first (Treatment A) and activity-based instruction second (Treatment B). As shown in Table 4-17, results of the repeated measures analysis of variance indicated significant differences between the pretest and posttest 2 means for Group A for 9 of the 12 knowledge questions. A Bonferroni correction was employed for the 12 ANOVAs by dividing the preset overall 0.05 significance level by the number of items (12) resulting in a significance level of .004167. The null hypothesis was rejected since exposure to the combined treatment of presenting video-based instruction first and activity-based instruction second significantly improved knowledge regarding the physics of car crashes on 75% of the knowledge test items.

Table 4-16. Mean Scores and Standard Deviations for Knowledge Items 1-12, Group A, Pretest - Posttest 2 for Combined Treatment

		Group A	
Item Number	Source	M	SD
1	Pretest	.4394	.5001
	Posttest 2	.9545	.2099
2	Pretest	.9090	.2897
	Posttest 2	1.000	0
3	Pretest	.5151	.5036
	Posttest 2	.8788	.3289
4	Pretest	.4697	.5029
	Posttest 2	.5303	.5029
5	Pretest	.3788	.4888
	Posttest 2	.9848	.1231
6	Pretest	.9242	.2666
	Posttest 2	.8788	.3289
7	Pretest	.1667	.3755
	Posttest 2	.8485	.3613
8	Pretest	.1212	.3289
	Posttest 2	.6667	.4750

Table 4-16. Continued

		Group A	
Item Number	Source	M	SD
9	Pretest	.9848	.1230
	Posttest 2	.9545	.2099
10	Pretest	.3485	.4801
	Posttest 2	.5909	.4954
11	Pretest	.3787	.4889
	Posttest 2	.7727	.4222
12	Pretest	.7576	.4318
	Posttest 2	.7273	.4488

Note: Group A = video-based instruction followed by activity-based instruction

Table 4-17. Source Table for the Repeated Measures Analysis for Knowledge Items 1-12, Group A, Pretest and Posttest 2 for Combined Treatment

Item Number	F	P
1	54.22	.0001*
2	7.87	.0006*
3	31.54	.0001*
4	13.59	.0001*
5	110.27	.0001*
6	.59	.5580
7	96.32	.0001*
8	101.79	.0001*
9	.49	.6132
10	10.41	.0001*
11	29.99	.0001*
12	1.18	.3108

* Significant at the .004167 level

Student attitudes toward seat belt use were measured using 10 questions with Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use (see Appendix A-2).

Hypothesis 8: The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in attitudes regarding seat belt use.

To test this hypothesis, pretest scores and posttest 2 scores of students in Group A were compared. Posttest 2 was administered after completing the combined treatment of presenting video-based instruction first (Treatment A) and activity-based instruction second (Treatment B). Table 4-18 provides the pretest and posttest 2 attitude assessment means for Group A. As shown in Table 4-19, the results of the repeated measures analysis of variance indicated no significant differences between pretest and posttest 2 attitude scores (alpha = 0.05). The null hypothesis was not rejected since the combined treatment of presenting video-based instruction first and activity-based instruction second did not result in significantly positive changes in attitudes regarding seat belt use.

Table 4-18. Mean Scores and Standard Deviations for Attitudes, Group A, Pretest – Posttest 2 for Combined Treatment

Source	Test	M	SD
Group A	Pretest	14.04	3.975
	Posttest 2	13.47	4.307

Table 4-19. Source Table for Repeated Measures Analysis of Variance of Attitudes, Group A, Pretest – Posttest 2 for Combined Treatment

Source		SS	df	MS	F	P
Group A	S	11.18	1	11.18	2.215	.141
	Error	338.3	67	5.049		

Student behavioral intentions toward seat belt use were measured using 20 questions. Three of the questions used Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use. The remaining 17 questions required the students to check items that described situations where they were more likely to wear a seat belt (see Appendix A-2).

Hypothesis 9: The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in behavioral intentions regarding seat belt use.

To test this hypothesis, pretest scores and posttest 2 scores of students in Group A were compared. Posttest 2 was administered after completing the combined treatment of presenting video-based instruction first (Treatment A) and activity-based instruction second (Treatment B). Table 4-20 provides the pretest and posttest 2 behavioral intention means for Group A. As shown in Table 4-21, the results of the repeated measures analysis of variance for the Likert-scale questions indicated significant differences between pretest and posttest 2 scores (alpha level 0.05). Analysis of the longer 17-item checklist indicated there was a significant difference between Group A's pretest and posttest 2 scores (see Table 4-22). The null hypothesis was rejected since the combined treatment of presenting video-based instruction first and activity-based instruction second resulted in significantly positive changes in behavioral intentions regarding seat belt use.

Table 4-20. Mean Scores and Standard Deviations of Behavioral Intentions Group A, Pretest – Posttest 2 for Combined Treatment

		Likert-Type Items		17 Item Checklist	
Source	Test	M	SD	M	SD
Group A	Pretest	5.824	2.987	12.08	4.339
	Posttest 2	4.897	2.444	13.85	4.075

Table 4-21. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, Group A, Likert-type Items, Pretest – Posttest 2 for Combined Treatment

Source		SS	df	MS	F	P
Group A	S	29.18	1	29.18	20.51	.000*
	Error	95.31	67	1.423		

* Significant at the 0.05 level.

Note: Group A = video-based instruction then activity-based instruction

Table 4-22. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, Group A, 17-Item Checklist, Pretest – Posttest 2 for Combined Treatment

Source		SS	df	MS	F	P
Group A	S	105.9	1	105.9	23.04	.000*
	Error	303.1	67	4.52		

* Significant at the 0.05 level.

Treatment Order and Interaction Effects

Additional analyses examined order effects and interactions between the two treatments used in the study. Student knowledge regarding the physics of car crashes relating to seat belt use was measured using 12 multiple-choice questions on the pretest, posttest one, and posttest two (see Appendix A-2). Table 4-23 provides pretest and posttests 2 knowledge test means and standard deviations for Group A (video-based lessons followed by activity-based lessons) and Group B (activity-based lessons followed by video-based lessons).

Hypothesis 10: The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater knowledge gains regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

To test this hypothesis, posttest 2 scores of students in Group A and Group B were compared. Posttest 2 was administered after completing the combined treatment of presenting video-based instruction first and activity-based instruction second (Group A) and activity-based instruction first and activity-based instruction second (Group B). As shown in Table 4-24, results of the Bonferroni procedure indicated no significant differences at the .004167 alpha level for 8 of the 12 questions regarding order effects and no significant differences at the .004167 alpha level for 11 of the 12 questions regarding interactions between the two treatments. The null hypothesis was not rejected since the combined treatment of presenting video-based instruction first and activity-based instruction second resulted in no significantly greater knowledge gains regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

Table 4-23. Mean Scores and Standard Deviations for Knowledge Items 1-12, Group A and Group B, Pretest - Posttest 2

		Group A		Group B	
Item Number	Source	M	SD	M	SD
1	Pretest	.4394	.5001	.4505	.5003
	Posttest 2	.9545	.2099	.8241	.3828
2	Pretest	.9090	.2897	.8681	.3402
	Posttest 2	1.000	0	.9780	.1074
3	Pretest	.5151	.5036	.4396	.4991
	Posttest 2	.8788	.3289	.8132	.3919
4	Pretest	.4697	.5029	.3187	.4689
	Posttest 2	.5303	.5029	.6703	.4727

Table 4-23 Continued

		Group A		Group B	
Item Number	Source	M	SD	M	SD
5	Pretest	.3788	.4888	.3956	.4917
	Posttest 2	.9848	.1231	.9670	.1795
6	Pretest	.9242	.2666	.9121	.2847
	Posttest 2	.8788	.3289	.8901	.3145
7	Pretest	.1667	.3755	.0440	.2061
	Posttest 2	.8485	.3613	.5055	.5027
8	Pretest	.1212	.3289	.0330	.1795
	Posttest 2	.6667	.4750	.5055	.5027
9	Pretest	.9848	.1230	.9341	.2495
	Posttest 2	.9545	.2099	.9451	.2291
10	Pretest	.3485	.4801	.2857	.4543
	Posttest 2	.5909	.4954	.4835	.5025
11	Pretest	.3787	.4889	.2637	.4431
	Posttest 2	.7727	.4222	.6484	.4801
12	Pretest	.7576	.4318	.7692	.4237
	Posttest 2	.7273	.4488	.9121	.2845

Note: Group A = video-based instruction followed by activity-based instruction
Group B = activity-based instruction followed by video-based instruction

Table 4-24. Source Table for the Repeated Measures Analysis for Knowledge Items 1-12,Group A and Group B, Pretest - Posttest 2

Item Number	Source	F	P
1	Order	2.14	.2230
	Interaction	1.52	.2099
2	Order	1.62	.2048
	Interaction	.22	.8050
3	Order	7.80	.0059
	Interaction	2.21	.1127
4	Order	.20	.6530
	Interaction	4.72	.0102
5	Order	1.25	.2658
	Interaction	2.30	.1040
6	Order	.66	.4183
	Interaction	1.83	.1647
7	Order	23.63	.0001*
	Interaction	3.52	.0320
8	Order	20.29	.0001*
	Interaction	4.88	.0088
9	Order	0.00	.0236
	Interaction	3.84	.2099
10	Order	13.41	.0003*
	Interaction	8.21	.0004*
11	Order	12.78	.0005*
	Interaction	2.54	.0819
12	Order	3.50	.0631
	Interaction	2.72	.0690

* Significant at the .004167 level.

Student attitudes toward seat belt use were measured using 10 questions with Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use (see Appendix A-2). Table 4-25 provides pretest and posttests 2 attitude test means for Group A (video-based lessons followed by activity-based lessons) and Group B (activity-based lessons followed by video-based lessons).

Hypothesis 11: The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive changes in attitudes regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

To test this hypothesis, posttest 2 scores of students in Group A and Group B were compared. Posttest 2 was administered after completing the combined treatment of presenting video-based instruction first and activity-based instruction second (Group A) and activity-based instruction first and activity-based instruction second (Group B). Table 4-26 provides the posttest 2 results of the attitude questions for Group Effects. There were no significant differences in the amount each intervention improved students' attitudes toward seat belt use, indicating that both combined treatments increased students' attitudes by the same amount. Although the posttest mean score for Group A was lower than their pretest score, indicating more positive attitudes toward seat belt use, the difference between the scores was not significant. Group B pretest and posttest attitude scores remained virtually unchanged. The null hypothesis was not rejected since the combined treatment of presenting video-based instruction first and activity-based instruction second resulted in no significantly greater positive changes in attitudes regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

Table 4-25. Mean Scores and Standard Deviations for Attitudes, Group A and B, Pretest – Posttest 2 Scores

Source	Test	M	SD
Group A	Pretest	14.04	3.975
	Posttest 2	13.47	4.307
Group B	Pretest	16.21	4.703
	Posttest 2	16.22	5.933

Table 4-26. Source table for Repeated Measures Analysis of Variance of Attitudes,Group A and Group B, Posttest 2 Scores

Source		SS	df	MS	F	P
Group (between)	S	6.787	1	6.787	.714	.399
	Error	1540	162	9.505		

Student behavioral intentions toward seat belt use were measured using 20 questions. Three of the questions used Likert-scale response scores ranging from 1 through 5, with 1 representing the strongest positive attitude toward seat belt use. The remaining 17 questions required the students to check items that described situations where they were more likely to wear a seat belt (see Appendix A-2). Table 4-27 provides pretest and posttests 2 behavioral intention test means for Group A (video-based lessons followed by activity-based lessons) and Group B (activity-based lessons followed by video-based lessons).

Hypothesis 12: The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive shifts in behavioral intentions regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

To test this hypothesis, posttest 2 scores of students in Group A and Group B were compared. Posttest 2 was administered after completing the combined treatment of presenting video-based instruction first and activity-based instruction second (Group A) and activity-based instruction first and activity-based instruction second (Group B). Tables 4-28 and 4-29 provide the posttest 2 mean comparisons of the Likert-scale and 17-item checklist questions regarding students' behavioral intentions. There was no significant difference in the amount each intervention improved students' behavioral intentions, indicating that both combined treatments increased behavioral intentions by the same amount. The null hypothesis was not rejected since the combined treatment of presenting video-based instruction first and activity-based instruction second resulted in no significantly greater positive shifts in behavioral intentions regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second

Table 4-27. Mean Scores and Standard Deviations of Behavioral Intentions, Group A and Group B, Pretest – Posttest 2

		Likert-Type Items		17 Item Checklist	
Source	Test	M	SD	M	SD
Treatment A	Pretest	5.824	2.987	12.09	4.339
	Posttest 2	4.897	2.444	13.85	4.075
Treatment B	Pretest	6.323	2.654	11.79	4.581
	Posttest 2	5.500	2.496	12.94	4.836

Table 4-28. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, Likert-type Items, Group A and Group B, Posttest 2 Scores

Source		SS	df	MS	F	P
Group (between)	S	24.18	1	24.18	2.007	.158
	Error	1952	162	12.05		

Table 4-29. Source table for Repeated Measures Analysis of Variance of Behavioral Intentions, 17-Item Checklist, Group A and Group B, Posttest 2 Scores

Source		SS	df	MS	F	P
Group (between)	S	29.24	1	29.24	.817	.367
	Error	5797	162	35.79		

Summary

This study examined the effects of video-based science instruction and accompanying activity-based instruction on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts. In addition, order effects and interactions between interventions were examined with each of the dependent variables. Quantitative data were used to determine if there were significant differences between the treatment groups in posttest measures of knowledge, attitudes, and behavioral intentions related to seat belt use.

The following research questions were examined:

1. What are the effects of Intervention A (exposure to video-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?
2. What are the effects of Intervention B (activity-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?
3. What are the effects of varying the sequence of presentation of Interventions A and B on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?

The results of the null hypotheses are presented below.

1. After participating in video-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

   Reject the null hypothesis.

2. After participating in video-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.

   Reject the null hypothesis.

3. After participating in video-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.

   Reject the null hypothesis.

4. After participating in activity-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

   Reject the null hypothesis.

5. After participating in activity-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.

   Do not reject the null hypothesis.

6. After participating in activity-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.

   Do not reject the null hypothesis.

7. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

   Reject the null hypothesis.

8. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in attitudes regarding seat belt use.

   Do not reject the null hypothesis.

9. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in behavioral intentions regarding seat belt use.

   Reject the null hypothesis.

10. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater knowledge gains regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

    Do not reject the null hypothesis.

11. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive changes in attitudes regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

    Do not reject the null hypothesis.

12. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive shifts in behavioral intentions regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

    Do not reject the null hypothesis.

Student knowledge regarding the physics of car crashes improved on 75% of test items regardless of type or sequence of treatments. Video alone, activities alone, and either combination were all equally effective in changing student knowledge. Regarding the affective component, the only treatment that resulted in significant positive changes in student attitudes toward seat belt use was the video alone. However, this positive change was short term since significant attitude gains were not maintained after completing the hands-on activities. In addition, neither activities alone nor activities followed by video instruction resulted in significant positive attitude changes. Behavioral intentions regarding seat belt use significantly improved as a result of three of the four treatments (video alone, video followed by activities, and activities followed by video). Participating in the activities only did not result in significant changes in behavioral intentions. Combining video-based instruction with activity-based instruction, in either order, produced greater gains in behavioral intentions than viewing only the video.

Activity-based instruction alone failed to produce significant gains in behavioral intentions to wear seat belts. Further discussion of these results and their implications follow in Chapter 5.

CHAPTER 5
SUMMARY, IMPLICATIONS, AND CONCLUSIONS

Chapter 5 is divided into four main sections. The first section reviews the objectives of the study. The second section summarizes and discusses the quantitative results from Chapter 4. The third section examines the implications for further research and how these implications could affect the design of driver safety education programs and curricula. The fourth section includes the conclusions of the study.

Review of the Study

This study examined the effectiveness of two different learning experiences in high school science classrooms that expose students to vehicle safety concepts and analyzed the impacts of these experiences on students' crash-safety physics knowledge, attitudes and behavioral intentions toward seat belt use. An educational science video was developed to address vehicle safety issues by providing viewers with many visual experiences designed to help assimilate the physics concepts involved in car crashes. The videotape was designed in conjunction with activity-based lessons to increase students' physics knowledge and direct experience with key motion concepts of inertia, energy, momentum, and impulse. The complementary activities provided additional hands-on exposure to these concepts. Secondarily, the purpose of this study was to determine order effects and interactions between the two types of learning experiences (video-based instruction and activity-based lessons).

The study was conducted with 10 intact classes, five introductory biology classes and five introductory chemistry classes in a medium-sized city in north central Florida. The school is unique in that it is a developmental research school and the demographics of the students enrolled are representative of the state's characteristics in terms of gender, ethnicity, and socioeconomic status. One hundred and ninety-four students participated in the study, and there were two instructors, one biology and one chemistry. The students were in their regular science classes during the study. The control group consisted of one introductory biology class and one introductory chemistry class. The other four introductory biology and four introductory chemistry classes served as the treatment group. A pretest-posttest1-posttest2 model was used for each group. The same instruments were used for both the pretest and posttests.

A pilot study was conducted prior to the study to collect reliability data for the researcher-designed knowledge, attitude, and behavioral intention assessments. The pilot study sample consisted of 41 high school science students not involved in the study. Cronbach's alpha was used for internal consistency analysis. The knowledge, attitude, and behavioral intention instrument scores for internal consistency were .19, .76, .95, respectively. The low reliability score of the knowledge instrument was attributed to the high difficulty and low number of items. With the reliability score too low to form a cognitive scale, each knowledge item was analyzed individually.

The knowledge assessment was researcher-designed and consisted of 12 multiple choice questions addressing physics concepts relating to vehicle collisions and safety features covered in the two week treatment. The attitude assessment, designed by the researcher, consisted of 10 items and a Likert-type response scale addressing students' attitudes toward seat belts and their use as covered in the curriculum. The behavioral intentions assessment was researcher-designed and consisted of three Likert-type questions and 17 Yes-No response items. The behavioral intentions instrument used in this study focused specifically on students' personal seat belt use.

Content validity of all three instruments was determined by sending copies of the assessment to four experts for review. A physics professor, a professor of science education, and a high school science teacher each completed a Science Content Validity Evaluation Form (see Appendix B-1) to rate science content accuracy and completeness. Each expert determined the science content of the knowledge questions was accurate and complete. An expert in the field of traffic safety evaluated the content validity of the attitude and behavioral intention questions. Suggestions were given for restructuring of three questions, one to include responses for different driving scenarios and two to change the responses to be answered in the negative.

The curriculum (see Appendices D and E) used in this study was developed by the researcher and the Insurance Institute for Highway Safety (IIHS), a nonprofit research and communications organization dedicated to reducing highway crash deaths, injuries, and property losses. The curriculum package consisted of a 22-minute videotape (see Appendix D for script) on the physics of automobile collisions and a supporting teacher guide. The researcher-developed guide included six activities, two to accompany the viewing of the video and four hands-on science activities, directed toward improving students' knowledge, attitudes, and behavioral intentions related to seat belt use.

Content validity of the video-based lessons was determined by sending copies of each of the two lessons to three science education experts. A professor of science education, a high school physics teacher with a graduate degree in science education, and an author of a high school physics textbook evaluated the education content and format of the video question sheets. Each expert's review supported the education content and format of the video question sheets.

Four science and three education experts reviewed the hands-on science activities for content validity. Two content validity evaluation forms were provided by the researcher to assess science content validity (see Appendix B-2) and science pedagogical validity (Appendix B-3). The two science content reviewers were a physics professor and a mechanical engineer. The science content reviewers were asked to rate content accuracy, completeness, and relevancy. One reviewer rated all six hands-on lessons as accurate and complete. The other three reviewers rated four of the six lessons as complete and accurate but each noted the same lesson as redundant. The content reviewers' concerns were addressed by reducing the number of hands-on activities from six to four.

Three educators–one national-board certified high school science teacher, one professor of science education, and an author of a high school physics textbook–were asked to rate the pedagogical validity of each lesson by looking for elements such as clear objectives, sufficient background information, age-appropriateness and accurate time estimates. Each rater scored 100% of the lessons as appropriate for the purposes of the study. Two reviewers commented on the redundancy of one of the lessons. The remaining reviewer commented that the lessons could easily be simplified or extended for varying age or ability levels.

All 194 students completed pretests prior to the initiation of the study. The pretests addressed each of the three outcome variables: 1) knowledge regarding the physics of car crashes relating to seat belt use, 2) attitudes regarding seat belt use, and 3) behavioral intentions regarding seat belt use. The treatment consisted of two video-based lessons (incorporating a researcher-developed, 22-minute videotape on the physics of car collisions) and four researcher-developed, activity-based science lessons. During the two-week treatment period, the same instrument was used for the pretest, posttest 1 and posttest 2.

The study sought to answer three questions related to science and driver education at the high school level. The questions are stated below.

1. What are the effects of Treatment A (exposure to video-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?

2. What are the effects of Treatment B (activity-based instruction) on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?

3. What are the effects of varying the sequence of presentation of Treatments A and B on the knowledge, attitudes, and behavioral intentions of high school students' use of seat belts?

This study's research hypotheses include the following:

1. After participating in video-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

2. After participating in video-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.

3. After participating in video-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.

4. After participating in activity-based instruction, students will have no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.

5. After participating in activity-based instruction, students will have no significant positive changes in attitudes regarding seat belt use.

6. After participating in activity-based instruction, students will have no significant positive changes in behavioral intentions regarding seat belt use.
7. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant gains in knowledge regarding the physics of car crashes relating to seat belt use.
8. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in attitudes regarding seat belt use.
9. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significant positive changes in behavioral intentions regarding seat belt use.
10. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater knowledge gains regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.
11. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive changes in attitudes regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.
12. The combined treatment of presenting video-based instruction first and activity-based instruction second will result in no significantly greater positive shifts in behavioral intentions regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

It was hypothesized that students who participated in video-based instruction with accompanying activity-based instruction would acquire more knowledge of the physics of car crashes related to seat belt use than students who did not participate in the treatments. It was also hypothesized that students who participated in the treatment would develop more positive attitudes toward seat belt use compared to students who were not exposed to science educational curriculum related to car crashes and seat belt use.

It was further hypothesized that the students who were exposed to the science lessons and activities would show more positive intentions to wear seat belts compared to students who did not receive the instruction. It was expected that the lessons and activities addressing knowledge would translate into a positive effect on attitudes and behavioral intentions toward seat belt use.

Because many learners need additional interventions to connect science concepts beyond simple hands-on activities (Ledbetter, 1993), it was hypothesized that students who first participated in video-based instruction followed by activity-based instruction would show significant gains in scores on a posttest measuring knowledge of the physics of car crashes related to seat belt use.

Summary of Results

1. There were significant differences in pretest and posttest 1 mean scores for video-based instruction on 9 of the 12 items measuring knowledge of the physics of car crashes related to seat belt use.

2. There were significant differences in pretest and posttest 1 mean scores for video-based instruction on student attitudes regarding seat belt use.

3. There were significant differences in pretest and posttest 1 mean scores for video-based instruction on student behavioral intentions regarding seat belt use.

4. There were significant differences in pretest and posttest 1 mean scores for activity-based instruction on 9 of the 12 items measuring knowledge of the physics of car crashes related to seat belt use.

5. There were no significant differences in pretest and posttest 1 mean scores for activity-based instruction on student attitudes regarding seat belt use.

6. There were significant differences in pretest and posttest 1 mean Likert-scale scores for activity-based instruction on student behavioral intentions regarding seat belt use. There were no significant differences in pretest and posttest 1 mean Checklist scores for activity-based instruction on student behavioral intentions regarding seat belt use.

7. There were significant differences in pretest and posttest 2 mean scores for the combined treatment of presenting video-based instruction first and activity-based instruction second on 9 of the 12 items measuring knowledge of the physics of car crashes related to seat belt use.

8. There were no significant differences in pretest and posttest 2 mean scores for the combined treatment of presenting video-based instruction first and activity-based instruction second on the measures of attitudes toward seat belt use.

9. There were significant differences in pretest and posttest 2 mean scores for the combined treatment of presenting video-based instruction first and activity-based instruction second on students' behavioral intentions regarding seat belt use.

10. There were no significant differences in posttest 2 mean knowledge scores regarding seat belt use for the combined treatment of presenting video-based instruction first and activity-based instruction second compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

11. There were no significant differences in posttest 2 mean attitude scores regarding seat belt use for the combined treatment of presenting video-based instruction first and activity-based instruction second compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

12. There were no significant differences in posttest 2 mean behavioral intention scores regarding seat belt use for the combined treatment of presenting video-based instruction first and activity-based instruction second compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second.

Discussion

The National Highway Traffic Safety Administration and the American Automotive Association Foundation for Traffic Safety recommends a complete overhaul of driver education curricula and delivery systems, and urge for continued research to examine new opportunities for driver education as a means of preventing collisions involving young motorists (Simpson, 1996). This study hypothesized that a fundamental shift in driver education pedagogy toward proven science instructional methods could change students' knowledge, attitudes and intended behaviors related to traffic safety and seat belt use. This study implemented a theoretically different approach to driver education by using an educational science video and accompanying hands-on science activities as the vehicle to support the rationale for using seat belts.

The results indicated that video-based instruction (Treatment A) markedly improved the students' understanding of the physics of car crashes. By providing students with a variety of visual experiences designed to illustrate the physics concepts involved in car crashes, the video was able to address several vehicle safety issues, including the importance of seat belt use. The gains in understanding of concepts as measured by the group means were statistically significant for 9 of the 12 knowledge questions. Participating in video-based instruction initially produced significant changes in students' attitudes but these changes were not maintained after students completed the activity-based instruction. After participating in video-based instruction, students showed significant positive changes in behavioral intentions regarding seat belt use.

Activity-based instruction (Treatment B) also produced significant gains in posttest 1 knowledge scores. The teacher-guided, hands-on science activities provided opportunities for direct experience with key crash-related motion concepts of inertia, momentum, impulse, and energy. The gains in understanding of concepts as measured by the group means were statistically significant for 9 of the 12 knowledge questions. The activity-based instruction group did not show significant changes in their attitudes toward seat belt use. Results for behavioral intentions were mixed. Analysis of the three Likert-type behavioral intention questions did show a significant positive change in behavioral intentions yet analysis of the 17-item checklist indicated there was no significant change. Due to the higher reliability score of the checklist section, it was concluded behavioral intentions to wear seat belts did not increase with activity-based instruction.

The combined treatment of presenting video-based instruction first and activity-based instruction second resulted in significant gains in 9 of the 12 knowledge questions regarding the physics of car crashes relating to seat belt use. Combining the treatments resulted in higher mean knowledge scores than either treatment did individually. The biggest difference occurred in knowledge questions directly addressing crash scenarios or applications of crash-related concepts (see Table 4-16, Items Numbers 5, 7, and 8). The question may be asked: Why was the combined treatment so successful in creating better understanding of key crash-related motion concepts? The answer to this question may in part be found in the science pedagogy and instructional technology literature.

Blumenfeld, Soloway, Marx, Krajcik, Guzdial, and Palincsar (1991) reported that student interests are enhanced when (a) tasks are varied and include novel elements, (b) problems are authentic and valuable, (c) problems are challenging, (d) there is closure through the creation of a product, (e) there is choice about what and/ or how work is done, and (f) there are opportunities to work with others. The video-based instruction and complementing teacher-guided, hands-on science activities were designed to address each of these factors. By involving students in high-interest, grade-level appropriate, and challenging activities they became actively involved in constructing their knowledge. The social constuctivist learning theory asserts that students learn by making connections between new information presented and their existing conceptual framework (Ausubel, 1963; Novak, 1979; Shapiro, 1994; Tobin, 1993; Vygotsky, 1986).

A major strategy in the design of the treatments was to present diverse contexts in which key crash-related concepts could be identified. This strategy provided an opportunity to construct and reinforce the concepts through a range of contexts. Ledbetter (1993) reported hands-on activity participation does not guarantee concept learning without additional interventions to tie the important science concepts to the hands-on activities. Ledbetter proved videotapes are effective and efficient in providing the additional interventions to link important science concepts to hands-on activities.

As a major component in the combined treatment, the video was written and produced following Chu & Schramm's (1967) and Newman's (1981) seven recommendations for effective instructional television:

1. Repeat key concepts in a variety of ways.
2. Make use of animation, novelty, variety, and simple visuals.
3. Entertain as well as inform.
4. Use a trained communicator (for adults: make use of nationally known personalities).
5. Provide opportunities for students to participate in a learning activity, either in response to information presented in a program or as part of a game presented by the program.
6. Match the length of the program to the attention span of the intended audience.
7. Follow the principles of effective audiovisual presentations.

Research has shown that students show gains in achievement from viewing instructional television when teachers provide reinforcing discussions and activities; therefore, complete teacher lesson plans were created by the researcher to follow the viewing. Based on the summary of instructional television research by Chu and Schramm (1967) and Newman (1981), the content and pedagogical format of the video question sheets addressed the following five research-based recommendations for increasing student achievement when viewing instructional television:

1. Prepare students to receive information presented by the film.
2. Provide reinforcing discussions and activities following viewing.
3. Provide corrective feedback to students, based on what students reveal they have understood from the program, in follow-up discussions between students and teacher.

4. Provide students with frequent feedback about their achievement as a result of viewing.
5. Assume an active role in the instruction that accompanies the viewing of television programs.

The combined treatment of presenting video-based instruction first and activity-based instruction second did not result in significant positive attitude changes regarding seat belt use. The theories of reasoned action (Ajzen & Fishbein, 1980) and planned behavior (Eiser, 1986) contend changes in attitude will come about only when a sufficient number of behavioral beliefs are changed. This suggests a possible explanation for the failure of the treatments or their combination to change students' attitudes toward seat belt use. The treatments address a limited number of concepts in a brief amount of time. Increasing the number of concepts or the time spent on each might produce a significant change in students' attitudes toward seat belt use.

The combined treatment of presenting video-based instruction first and activity-based instruction second resulted in significant positive changes in behavioral intentions regarding seat belt use. A number of researchers have applied some form of the theory of reasoned action to understand the use of seat belts (Budd, Noth, & Spencer, 1984; Fhaner & Hane, 1974; Fishbein, Slazar, Rodriguez, Middelstadt, & Himmelfrab, 1988; Wittenbaker, Gibbs, & Kahle, 1983). Consistent with the theory, a person's intention to wear a seat belt is a good predictor of seat belt use (Wittenbraker et al., 1983). Many research studies have reported strong correlations between knowledge, attitudes, and behavioral intentions (Wiegel & Newman, 1982). The increase in behavioral intention scores in this study is interesting because students' knowledge increased but their attitudes toward seat belt use remained nearly the same. Fishbein and Ajzen (1975) contend beliefs form the basis of attitudes, and that the strength of the attitude is dependent on the strength or confidence in the knowledge. While students' knowledge scores significantly improved, their confidence in their knowledge may not have been sufficiently high to change their attitudes; yet they may have been high enough to change their behavioral intentions.

The combined treatment of presenting video-based instruction first and activity-based instruction second did not result in significantly greater knowledge gains, significantly greater positive changes in attitudes, or significantly greater positive shifts in behavioral intentions regarding seat belt use compared to the combined treatment of presenting activity-based instruction first and video-based-instruction second. This runs counter to Linn's (1986) research on knowledge gains using advanced organizers. Linn suggested people are better prepared to learn a concept if they use an advance organizer. The video-based instruction was designed for this function. The ability of activity-based instruction to act as an advance organizer may account for no significant difference between the sequence of treatments.

Implications

This study's results lend further justification to the important relationship between knowledge, attitudes, and behavioral intentions in science education and provide a new perspective in the field of traffic safety. The data from this study indicated that a fundamental shift in driver education pedagogy toward proven science instructional methods can change students' knowledge and intended behaviors related to traffic safety and seat belt use. The United States Department of Health and Human Services (1991) reported an educational program with the ability to predict safety belt use in teenagers could lead to additional lives saved. The results of this study suggest that the combined treatment utilizing educational science video-based lessons combined with a set of teacher-guided, hands-on science activities can contribute to future driver safety programs.

When the inadequacies of our educational system are viewed from the perspective of vehicle crashes and deaths involving young drivers, a new emphasis on driver's education efforts in school reform becomes critical. Linking driver education with graduated licensing is emerging as a reform model with the potential for lowering young drivers' crash rates. The National Highway and Traffic Safety Administration's (NHTSA) graduated licensing model recommends two stages of driver education: a basic driver education course in the first or learner stage and an advanced driver education course in the second stage. The results of this study suggest that the science education community could play a key role in contributing to the success of graduated licensing programs. This study's educational science video and accompanying teacher-guided, hands-on science activities could support the more advanced safety-oriented course during the second stage of NHTSA's model.

In summary, there are four interrelated lines of argument that establish the significance of this study. First, the study advances knowledge in the fields of science education and traffic injury research. Second, it contributes to the development of more effective driver education curricula and practices. Third, it demonstrates a novel use of a proven effective instructional strategy. And fourth, it is part of a programmatic research effort to reduce young adult injuries and fatalities in vehicle collisions.

Limitations

The study has several limitations to generalization. As reported in Chapter One, one limitation was the geographic population from which the sample was drawn (high school students enrolled in introductory science classes at a university laboratory school in northeast Florida). Another limitation was students could not be randomly assigned for the investigation; thus intact classes were used for cluster random sampling. The effects of the teachers and the lack of fidelity of implementation of the lessons were limitations in this study. The researcher was not present for implementation of each of the lessons and only consulted with the teachers upon request. More data documenting the fidelity of lesson presentation would allow the researcher to be more confident drawing conclusions from the analyses of the data. With a total of only 194 students, another threat to the validity was the small sample size used in this study. Increases in sample sizes would add validity to the study.

Another limitation of the study was incomplete data regarding the control group. The control group only completed the pretest and posttest 2. No posttest 1 was administered. With only pretest and posttest 2 data, it was not possible to compare all control group and treatment group posttest scores. Yet, analyses comparing the control group's pretest and posttest two scores indicated no significant increases in attitudes regarding seat belt use or behavioral intentions to wear seatbelts. Due to the low overall reliability of the knowledge instrument, control group pre and posttest knowledge scores could not be analyzed for changes. The primary purpose of the study was to determine if video-based instruction and activity-based instruction could significantly improve student knowledge, attitudes, and behavioral intentions regarding set belt use. This study was able to accomplish this goal. However, if complete control group data were available for both posttests, a comparison of treatment and control group knowledge, attitude, and behavioral intention scores would have strengthened the findings of this study.

The instruments used also limited the study. The instruments consisted of researcher-designed items as well as items drawn from other driver safety research instruments. The low reliability score of the knowledge instrument was attributed to the high difficulty and low number of items. With the reliability score too low to form a cognitive scale, each knowledge item was analyzed individually. With this in mind, a more conservative alpha (.004167) was used to test for significance to reduce the likelihood that differences in test scores were due to test-retest reliability. The instruments were tested during a pilot study that included a small sample of 41 students. Continued instrument testing and revising using a larger study sample could increase their validity and reliability.

Another factor concerning the limitations of the study was the lack of follow-up assessment to document any long term changes in students' knowledge, attitude, or behavioral intentions. Repeated testing six months or one year later would allow the researcher to be more confident drawing conclusions from the analyses of the data. Also, no follow-up assessment was used to document the students' actual change in behavior; only behavioral intentions were assessed. Self-reported belt use may have been higher than actual use. Additional studies designed to make unobtrusive observations of belt use in the study's population would increase the validity of results.

Conclusion

A need exists to examine critically both the existing methods and the systems of delivery for driver education and training (Insurance Bureau of Canada, 1991). This study investigated one possible intervention, the use of an educational science video and accompanying teacher-guided, hands-on science activities designed to change students' knowledge, attitudes, and behavioral intentions related to traffic safety and seat belt use. This combined intervention appeared effective in providing the support to tie key motion concepts of inertia, momentum, impulse, and energy to major driver safety themes. Completing video-based instruction and accompanying activity-based instruction resulted in significant changes in knowledge and behavioral intentions but did not affect students' attitudes toward seat belt use. Further studies are needed to investigate whether the gains in understanding the students made are short or long-term and the extent to which an increase in behavioral intentions leads to actual behavioral change. A longitudinal study of the students who participated in this study would be desirable.

Research shows that current driver education programs have been unable to affect the crash risk of young drivers and, therefore, the safety value of these programs remains unproven (Mayhew & Simpson, 1996). An emerging cooperative spirit between the research community and educators is defining the search for innovative ways to improve driver education (Simpson, 1995). This study proposed in addition to changing what is taught to novice drivers, there needs to be a change in how it is taught. Further research in driver safety education strategies and the use of science instructional methods is needed to determine the most effective way to reduce young adult injuries and fatalities in vehicle collisions.

APPENDIX A
INSTRUMENTS

Pre-assessment Survey: Understanding Car Crashes: It's Basic Physics!

Directions: Please place a check (√) in the blank to the left of your response.

1. Do you drive a car?
____ Yes
____ No

2. Which of the following applies to you?
____ I have a learner's permit
____ I have a driver's license.
____ I do not have a learner's permit or driver's license.

Please write numbers in the blanks for your response.

3. How long have you had a driver's license or permit?
______ Years _______Months

4. How old are you? ______ years

* SELF-REPORT OF PAST BEHAVIOR

- For this study, please consider a motor vehicle as a car, sport utility vehicle (SUV), truck, or van (do not include school or public buses).

5. Circle the number indicating how often each of the following wear a safety belt.

1= Never
2 = Seldom
3 = Sometimes
4 = Most of the time
5 = Always
6 = Does not apply

You as a driver	1	2	3	4	5	6
You as a passenger / rider in the front seat	1	2	3	4	5	6
You as a passenger / rider in the back seat	1	2	3	4	5	6
Your mother / stepmother / female guardian	1	2	3	4	5	6
Your father / stepfather/ male guardian	1	2	3	4	5	6
Your brother / sister you ride or drive with most	1	2	3	4	5	6
Your girlfriend / boyfriend	1	2	3	4	5	6
Your best friend	1	2	3	4	5	6

6. About how often do you ride in a motor vehicle? (car, sport utility vehucle, truck or van) (do not

Check (√) ONLY ONE.
_____ Almost every day

_____ Few days a week

_____ Few days a month

_____ Few days a year

_____ Never

Other - (Specify)

7. Approximately, when was the last time you did **NOT** wear your seat belt when riding in a vehicle?

Check (√) ONLY ONE.

_______ Today

_______ Within the past week

_______ Within the past month

_______ Within the past year

_______ A year or more ago / I always wear it

_______ I never wear one

8. When I wear my seat belt, I do so because:

Check (√) any or all that apply.

_______ It's a habit.

_______ I don't want to get a ticket.

_______ I'm uncomfortable without it.

_______ Others want me to wear it.

_______ It's the law.

_______ I want to avoid serious injury.

_______ Other (Specify) ____

9. Of the following reasons you just gave for wearing your seat belt, which is the MOST important?

Check (√) ONLY ONE.

_______ It's a habit

_______ I don't want to get a ticket

_______ I'm uncomfortable without it

_______ Others want me to wear it

_______ It's the law

_______ I want to avoid serious injury

_______ Can't say one is most important/all are important

_______ Other (Specify) ____

10. Sometimes I do **NOT** wear my seat belt because:

Check (√) any or all that apply.

______ I'm only driving a short distance

______ I'm driving in light traffic.

______ I'm in a rush.

______ I'm riding in the back seat.

______ I'm a passenger in the front seat.

______ I forget to put it on.

______ I don't want my clothes to get wrinkled.

______ The seat belt is uncomfortable.

______ The probability of being in a crash is low.

______ None of my friends wear seat belts.

______ Other (Specify) ____

11. Of the following reasons you just checked for **NOT** wearing your seat belt, which is the MOST important?

Check (√) ONLY ONE.

______ I'm only driving a short distance.

______ I'm driving in light traffic.

______ I'm in a rush.

______ I'm riding in the back seat.

______ I'm a passenger in the front seat.

______ I forget to put it on.

______ I don't want my clothes to get wrinkled.

______ The seat belt is uncomfortable.

______ The probability of being in a crash is low.

______ None of my friends wear seat belts.

______ Can't say one is most important / all important.

______ Other (Specify) ____

12. Have you ever asked drivers or passengers to put on their safety belts?

Check (√) ONLY ONE.

______ Yes

______ No

13. If yes, how often?

Check (√) ONLY ONE.

______ All of the time

______ Most of the time

______ Some of the time

______ Rarely

______ Never

______ Don't know

What Others Think About Your Behavior.

14. Check how you think others feel about you using a seat belt.

	Cares Strongly	**Cares a little bit**	**Does Not Care**
Mother / step mother / female guardian			
Father / step father / male guardian			
Grandparents			
Favorite Teacher			
Brother / Sister I ride or drive with most			
Girlfriend / Boyfriend			
Friends			

How Do Others Affect Your Behavior?

15. Check how the following people influence you to wear or not to wear a seat belt.

	Strong Influence to wear a Seat Belt	**Weak** Influence to wear a Seat Belt	**No** Influence to wear a Seat Belt	**Weak** Influence **NOT** to wear a Seat belt	**Strong** Influence **NOT** to wear a Seat Belt
Mother / step mother / female guardian					
Father / step father / male guardian					
Grandparents					
Favorite Teacher					
Brother / Sister I ride or drive with most					
Girlfriend / Boyfriend					
Friends					

Understanding Car Crashes: It's Basic Physics!

Please follow the directions below **AFTER VIEWING THE VIDEO*.**

* * KNOWLEDGE OF CRASH-RELATED PHYSICS CONCEPTS

Directions: Write the letter of your answer in the blank to the left.

_______ 1. The property of matter to resist any change in its state of motion is

a) acceleration.
b) friction.
c) inertia.
d) velocity.

_______ 2. Imagine you are a passenger seated in the front seat of a car traveling 35 mph. Suddenly, the driver slams on the brakes, and you are NOT wearing a seat belt. Which of the following will happen?

a) Your body continues traveling 35 miles per hour until it hits the dashboard and windshield.
b) Your body slows down with the car.
c) Your body is so heavy that it does not move from the seat.
d) Your body braces itself and does not move from the seat.

_______ 3. Identify the following law of motion: A body at rest remains at rest unless acted upon by an external force, and a body in motion continues to move at a constant speed in a straight line unless it is acted upon by an external force.

a) Conservation of Energy Law
b) Newton's First Law of Motion
c) Newton's Second Law of Motion
d) Newton's Third Law of Motion

_______ 4. The momentum of an object is defined as the object's:

a) mass x acceleration
b) mass x velocity
c) force x acceleration
d) force x time

_______ 5. Which has more momentum, an 80,000 pound big trailer-truck rig traveling 2 mph or a 4,000 pound sport utility vehicle (SUV) traveling 40 mph?

a) Big trailer-truck rig
b) Sport utility vehicle (SUV)
c) They have the same momentum.

_______ 6. Which has more momentum, a sports car moving 30 miles per hour or the same sports car moving at 60 miles per hour?

a) The car moving at 30 miles per hour.
b) The car moving at 60 miles per hour.
c) Both have the same momentum.

_________ 7. Seat belts and airbags:

a) increase the force of impact in a collision.
b) spread the impact force over a longer time.
c) increase the momentum of a collision.
d) decrease the impulse in a collision.

_________ 8. An egg does not break when dropped onto a pillow because the:

a) velocity of impact is reduced.
b) momentum of impact is reduced.
c) time of impact is increased.
d) time of impact is decreased.

_________ 9. A race car driver is more likely to die when his/her race car:

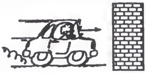
a) brakes slowly to a stop.
b) crashes directly or head-on into a wall.
c) hits the wall with the side of the car and slides to a stop.
d) spins several times and skids to a stop.

_________ 10. Which of the following does NOT protect people by extending the time of impact during a collision?

a) anti-lock brakes
b) break-away light poles
c) crumple zones
d) safety cage

_________ 11. When a car crashes into a brick wall the front end of the car crunches and absorbs:

a) acceleration.
b) energy.
c) inertia.
d) momentum.



_________ 12. Kinetic energy is the energy an object has because of its:

a) density.
b) location.
c) speed.
d) temperature.

Please follow the directions below **AFTER VIEWING THE VIDEO***.

DIRECTIONS: Circle the number that matches how you feel about each sentence. There are no right or wrong answers and this sheet will not be graded.

	Strongly Agree	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
**** BEHAVIORAL INTENTION**					
1. I plan to wear my seat belt the next time I drive or ride in a motor vehicle.	1	2	3	4	5
2. I plan to wear my seat belt all the time.	1	2	3	4	5
3. I plan to ask others riding with me to wear their seat belts.	1	2	3	4	5
4. I am less likely to wear a seat belt because it may keep me from escaping from a damaged vehicle after a crash.	1	2	3	4	5
**** ATTITUDE TOWARD THE BEHAVIOR**					
5. People will think I am a poor driver (or they are a poor driver) if I wear a seat belt.	1	2	3	4	5
6. Seat belts do more harm than good in a collision.	1	2	3	4	5
7. I think wearing a seat belt when driving or riding in a vehicle is nerdy.	1	2	3	4	5
**** BEHAVIORAL BELIEFS**					
8. My wearing of a seat belt would protect me from injury in a collision.	1	2	3	4	5
9. My wearing of a seat belt would increase my chance of surviving a serious automobile accident.	1	2	3	4	5
10. My wearing of a seat belt keeps me from receiving a ticket from a police officer.	1	2	3	4	5
**** OUTCOME EVALUATION**					
11. A device that protects me from injury in a collision is a good thing.	1	2	3	4	5
12. Increasing my chance of survival in a collision is a good thing.	1	2	3	4	5
13. Not receiving a ticket from a police officer is a good thing.	1	2	3	4	5
**** SUBJECTIVE NORM**					
14. Most people who are important to me think I should wear a seat belt.	1	2	3	4	5

Please follow the directions below **AFTER VIEWING THE VIDEO*.**

Check (√) any or all that apply.

15. I am more likely to wear a seat belt when:

______ traveling at a high speed (greater than 40 mph).

______ traveling at a lower speed (less than 40 mph).

______ traveling a long distance on a highway.

______ traveling a short distance in town.

______ traveling in a small, light car (compact car).

______ traveling in a truck or sport utility vehicle (SUV).

______ traveling in bad weather (heavy rain, fog, wind, snow, ice on the roads).

______ traveling in heavy traffic.

______ traveling at night.

______ my mother is in the car.

______ my father is in the car.

______ riding with one other friend.

______ riding with several of my friends.

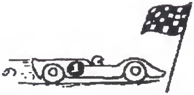
______ driving or riding in the front seat.

______ riding in the back seat.

______ going to a party.

______ coming home from a party.

That completes the survey. Thank you for your time and effort!



* Heading will be modified for Pretest (Before Watching the Video or Doing the Activites), Postest I (After Viewing the Video) , and Postest II (After Completing the Activities).

** Headings for each component of the test (e.g., SELF-REPORT OF PAST BEHAVIOR, BEHAVIORAL INTENTIONS) will not appear on the instrument given to the students.

APPENDIX B
CONTENT VALIDITY FORMS

B-1

CONTENT VALIDITY EVALUATION FORM
SCIENCE CONTENT OF LESSONS

Please review the enclosed lessons for science content. I have enclosed a response sheet for each lesson.

Lesson Name ______________________________________

Evaluator Name ____________________________________

Please indicate your response by circling yes (Y), no (N), or undecided (U). Please elaborate in the "Comments" section as needed.

1. Is the science content accurate? Y N U
2. Is the science content up to date? Y N U
3. Are there any misconceptions or inaccuracies in the lessons? Y N U
4. Are there any key ideas missing? Y N U
5. Is the background information accurate? Y N U
6. Are the materials appropriate for the lesson? Y N U
7. Do the lesson activities effectively illustrate the science concepts? Y N U
8. Is there sufficient coverage of the science content in the lessons? Y N U
9. Are the science topics important concepts for students to know? Y N U
10. Are the vocabulary terms accurate? Y N U

Comments ______________________________________

____

____

B-2
CONTENT VALIDITY EVALUATION FORM
SCIENCE CONTENT OF ASSESSMENT ITEMS 1 - 12

Please review the enclosed assessment for science content. I have enclosed a response sheet for the assessment.

Instrument Section: Knowledge of Crash-Related Physics Concepts, items 1-12.
Evaluator Name ____

Please indicate your response by circling yes (Y), no (N), or undecided (U). Please elaborate in the "Comments" section as needed.

1. Is the science content accurate? Y N U
2. Is the science content up to date? Y N U
3. Are there any misconceptions or inaccuracies in the questions? Y N U
4. Are there any key ideas missing? Y N U
5. Do the questions effectively illustrate the science concepts? Y N U
6. Is there sufficient coverage of the science content in the assessment? Y N U
7. Are the science topics important concepts for students to know? Y N U
7. Do the question choices cover the appropriate concepts for the topics? Y N U
9. Are the vocabulary terms accurate? Y N U
10. Are the concepts addressed valuable for physics education? Y N U

Comments ____

____

____

B-3
CONTENT VALIDITY EVALUATION FORM
PEDAGOGICAL VALIDITY OF LESSONS

Please review the enclosed lessons for pedagogical content. I have enclosed a response sheet for each lesson.

Lesson Name ____

Evaluator Name ____

Please indicate your response by circling yes (Y), no (N), or undecided (U). Please elaborate in the "Comments" section as needed.

1. Are the objectives clearly stated? Y N U
2. Are the objectives valuable for physics education? Y N U
3. Are the activities appropriate for the lesson topics? Y N U
4. Are the activities applicable to physics education? Y N U
5. Is the lesson appropriate for 9th and 10th grade high school students? Y N U
6. Are the materials appropriate for the lesson? Y N U
7. Is the amount of background information adequate? Y N U
8. Are the vocabulary terms used appropriate for 9th and 10th grade high school students? Y N U
9. Is the content sufficiently covered in enough depth for students to grasp the concepts? Y N U
10. Does the lesson encourage active student involvement? Y N U
11. Are the lesson plans clear enough for teachers to follow? Y N U
12. Are the directions clear? Y N U
13. Are the materials required reasonable? Y N U
14. Are the time estimates appropriate? Y N U
15. Are the activities relevant to 9th and 10th grade students interests? Y N U

Comments ____

____

____

APPENDIX C
TABLE OF SPECIFICATIONS

SCIENCE CONCEPTS	NUMBER OF LESSONS	PERCENT OF LESSONS	NUMBER OF TEST QUESTIONS	PERCENT OF QUESTIONS
Inertia	1.5	25%	3	25%
Momentum	1.5	25%	3	25%
Impulse	2.0	33%	4	33%
Energy	1	17%	2	17%
Totals	6	100%	12	100%

APPENDIX D
VIDEO SCRIPT

UNDERSTANDING CAR CRASHES: IT'S BASIC PHYSICS

Insurance Institute For Highway Safety

Key for timing: (hours: minutes: seconds: frames), counted from first frame of picture at 01 hours, one second = 30 frames.

(01:00:03:12) ***Announcer:*** Gentlemen, start your engines…

(01:00:10:05) ***Crew Member:*** Green, green, green…

(01:00:38:12) ***Jones:*** These drivers lost control at very high speeds. The result was tragic for one driver…and fortunate for the others. But why? What made the difference between walking away and being carried away? The answer can be found in some of the most basic laws of the physical universe.

(01:01:05:22) Hi, my name is Griff Jones. I teach high school physics and behind me is the Insurance Institute for Highway Safety's Vehicle Research Center. It's a fascinating place where research engineers assess the crash performance of vehicles by running tests. And where they evaluate new technologies to prevent injuries, like this state-of-the-art head protection system.

(01:01:29:00) What's exciting for me is that this is a laboratory of practical applications in the subject I teach. And because they're set up here to crash cars and analyze those crashes, this research center provides the perfect venue for illustrating the physical laws that govern the outcome of car crashes.

(01:01:46:26) So follow me and for the next few minutes I'll take you behind the scenes where we can explore the basic science behind vehicle crashes. Let's learn about car crashes and physics.

(01:02:00:08) Why'd this dummy get left behind? It's called inertia, the property of matter that causes it to resist any change in its state of motion. Galileo introduced the concept in the late 1500's and almost 100 years later, Newton used this idea to formulate his first law of motion, the law of inertia. It's why the dummy fell off the back of the truck. It was at rest and it wanted to remain at rest. That's inertia.

(01:02:22:22) It's the same property that keeps the china on the table as you pull the tablecloth out from under it.

(01:02:34:16) Now what about a body in motion? Am I a body in motion? You bet I am. I'm moving 35 miles-per-hour. But from one perspective it may not look like I'm moving at all because in relationship to the passenger compartment, my position isn't changing. But if you look at me from the outside, you can see that I'm moving at the same speed as the vehicle — in this case, about 35 miles-per-hour.

(01:02:56:28) And if Newton was right, and we know he was, I'm going to keep on moving at this same speed until an external force acts on me. Now what does this mean to occupants of a moving vehicle? Watch this…

(01:03:11:20) See how the car and the crash test dummy are traveling at the same speed? Now watch what happens when the car crashes into the barrier. The front end of the car is crushing and absorbing energy, which slows down the rest of the car. But the dummy inside keeps on moving at its original speed until it strikes the steering wheel and windshield.

(01:03:33:04) This is because the dummy is a body in motion traveling at 35 miles-per-hour and remains traveling 35-miles-per-hour in the same direction until acted upon by an outside force.

(01:03:45:03) In this case, it's the impact of the steering wheel and windshield that applies the force that overcomes the dummy's inertia. Inertia is one reason that seatbelts are so important. Inertia is one reason that you want to be tied to the vehicle during a crash.

(01:03:59:16) If you're wearing your seatbelt, you slow down with the occupant compartment as the vehicle's front end does its job of crumpling and absorbing crash forces. Later we'll talk about how some vehicles' front ends, or crumple zones, do a better job of absorbing crash forces than others.

(01:04:18:13) But for now, let's get back to Newton. He explained the relationship between crash forces and inertia in his second law and the way it's often expressed is F=ma. The force "F" is what's needed to move the mass "m" with the acceleration "a." Newton wrote it this way. It's the same thing. Acceleration is the rate at which the velocity changes. But if I multiply each side of the equation by "t," I get force times time equals mass times the change in velocity. When Newton described the relationship between force and inertia, he actually spoke in terms of changing momentum with an impulse. What do these terms mean?

(01:05:05:05) Momentum is inertia in motion. Newton defined it as the quantity of motion. It's the product of an object's mass, it's inertia, and it's velocity or speed. Which has more momentum: an 80,000-pound big rig traveling two miles-an-hour or a 4,000-pound SUV traveling 40 miles-per-hour? The answer is, they both have the same momentum. Here's the formula: "p" is for momentum — I don't know why they use "p," they just do — equals "m" is for mass, and "v" is for velocity...p=mv…that's momentum.

(01:05:49:16) And what is it that changes an object's momentum? It's called an impulse. It's the product of force and the time during which the force acts. Impulse equals force times time. Here's my favorite demonstration of impulse. I have two eggs, same mass. I'm going to try and throw each egg with the same velocity. That means they have the same momentum. If the impulses were equal, why do we have such dramatically different results? The wall applies a big stopping force over a short time. The sheet applies a smaller stopping force over a longer time period. My students say the sheet has more give to it. Both stop the egg, both decelerate the egg's momentum to zero, but it takes a smaller force to reduce the egg's momentum over a longer time. In fact, so much smaller that it doesn't even crack the egg's shell. Now let's relate this to automobiles. **(01:06:53:08)** Both of these cars have the same mass and both are traveling at the same speed, 30 miles-per-hour. Like the eggs, they have equal momenta. As a result, it will take equal impulses to reduce their momenta to zero. One car will stop by panic braking and the other by normal breaking. If both drivers are belted so they decelerate with their vehicles, the driver of the car on the bottom will experience more force than the driver on top. This is because if the impulses must be equal to decelerate each car's momentum to zero, the driver that stops in less time or distance must experience a larger force and a higher deceleration.

(01:07:38:03) A “g” is a standard unit of acceleration or deceleration. People often refer to g’s as forces, but they’re not. Fighter pilots can feel as many as 9 g’s when accelerating during extreme maneuvers. And astronauts have felt as many as 11.

(01:07:58:20) People in serious car crashes experience even higher g’s and this can cause injury. Now consider what happens when a car traveling 30 miles-per-hour hits a rigid wall, which shortens the stopping time or distance much more than panic braking. Let’s again assume the driver is belted and decelerates with the passenger compartment. And let’s also assume the car’s front end crushes one foot with uniform deceleration of the passenger compartment throughout the crash.

(01:08:28:29) In this crash, the driver would experience 30 g’s. However, if the vehicle’s front end was less stiff, so it crushed two feet instead of one, the deceleration would be cut in half to 15 g’s. This is because the crush distance, or the time the force is acting on the driver, is doubled. Extending the time of impact is the basis for many of the ideas about keeping people safe in crashes. It’s the reason for airbags and crumple zones in the vehicles you drive. It’s the reason for crash cushions and breakaway utility poles on a highway. And it’s the answer to the question I posed at the beginning of this film.

(01:09:13:05) This driver survived the crash because his deceleration from high speed took place over a number of seconds. This driver decelerated a small fraction of a second and experienced forces that are often unsurvivable.

(01:09:29:14) Up to now, we’ve been looking at single vehicle crashes. But if we look at two or more objects colliding, we have to use another one of Newton’s laws to explain the result. Even though the first cars wouldn’t appear on the roads for over 200 years, collisions were an active topic of physics research in Newton’s day. Back in 1662, Newton and his buddies formed one of the first international science clubs. They call it the Royal Society of London for Improving Natural Knowledge. One of the first experiments they did was to test Newton's theories on collisions using a device like this. **(01:10:04:24)** What do you think's going to happen when I release this ball and it collides with the others? Let's try two. It's as if something about the collision is remembered or saved. Newton theorized that the total quantity of motion, which he called momentum, doesn't change. It's conserved. This became known as the law of conservation of momentum and it's one of the cornerstone principles of modern physics. **(01:10:42:00)** Before we apply this to crashing cars, we need to know something else about momentum. It has a directional property, so we call momentum a vector quantity. This means if identical cars traveling 30 miles-per-hour collide head-on, their momenta cancel each other. Inside the passenger compartment of each car, the occupants would experience the same decelerations from 30 miles-per-hour to zero. The dynamics of this crash would be the same as a single vehicle crash into a rigid barrier.

(01:11:18:10) What conservation of momentum tells us about collisions of vehicles of different masses has important implications for the occupants of both the heavier and lighter vehicle. In a collision of two cars of unequal mass, the more massive car would drive the passenger compartment of the less massive car backward during the crash causing a greater speed change in the lighter car than the heavier car.

(01:11:41:19) These different speed changes occur during the same time, so the occupants of the lighter car would experience much higher accelerations, hence much higher forces than the occupant of the heavier car. This is one reason why lighter, smaller cars offer less protection to the occupants than larger, heavier cars.

(01:12:01:14) There's a difference between weight and size advantage in car crashes. Size helps you in all kinds of crashes.

(01:12:13:07) Weight is primarily an advantage in a crash with another vehicle.

(01:12:25:16) Newton was a pretty brilliant guy. The laws of motion he advanced over 300 years ago are still used today to explain the dynamics of modern-day events like car crashes. But even Newton failed to recognize the existence of energy. Even though it's all around us, energy is tough to conceptualize. Scientists have had difficulty defining energy because it exists in so many different forms.

(01:12:52:18) It's usually defined as the ability to do work, or, as one of my students says, it's the stuff that makes things move. Energy comes in many forms. There's radiant, electrical, chemical, thermal, and nuclear energy.

(01:13:08:26) In relating the concept of energy to car crashes though, we're mostly concern with motion-related energy…kinetic energy.

(01:13:19:12) Moving objects have kinetic energy. A baseball thrown to a batter…a diver heading toward the water…an airplane flying through the sky…a car traveling down the highway all have kinetic energy.

(01:13:38:23) But energy doesn't have to involve motion. An object can have stored energy due to its position or its condition. This is a device that delivers a force to a crash dummy's chest to test the stiffness of the ribs. The force is a result of the kinetic energy being transferred from the pendulum to the dummy's chest.

(01:13:58:27) As the pendulum sits at its ready position, its potential energy is equal to its kinetic energy at impact. When it is released, and begins traveling towards the dummy's chest, the potential energy transforms into kinetic energy.

(01:14:12:11) If we freeze the pendulum halfway, what is its potential versus kinetic energy? They're equal. When has the pendulum reached its maximum kinetic energy? Here, at the bottom of its swing.

(01:14:28:23) The amount of kinetic energy an object has depends upon its mass and velocity - the greater the mass, the greater the kinetic energy - the greater the velocity, the greater the kinetic energy. The formula that we use to calculate the kinetic energy looks like this: "KE," that's kinetic energy, equals one half "m" "v" squared, that's the velocity multiplied by itself. And if you do the math, you'll see why speed is such a critical factor in the outcome of a car collision. The kinetic energy is proportional to the square of the speed. So if we double the speed, we quadruple the amount of energy in a car collision. And energy is the stuff that has potential to do damage.

(01:15:16:12) The connection between kinetic energy and force is that in order to reduce the car's kinetic energy, a decelerating force must be applied over a distance. That's work.

(01:15:27:08) To shed 4 times as much kinetic energy requires either a decelerating force that's 4 times as great, or 4 times as much crush distance, or a combination of the two.

(01:15:40:17) The rapid transfer of kinetic energy is the cause of crash injuries. So managing kinetic energy is what keeping people safe in car crashes is all about.

(01:15:52:17) Brian O'Neill is the president of the Insurance Institute for Highway Safety.

(01:16:02:27) ***O'NEILL:*** One of the things we do, we put grease paint…

(01:16:05:17) ***JONES:*** He runs the Vehicle Research Center and is one of the foremost experts in the world on vehicle safety.

(01:16:12:22) ***O'NEILL:*** We use the term "crashworthiness" to describe the protection a car offers its occupants during a crash. Now crashworthiness is a complicated concept because it involves many aspects of vehicle design. The structure, the restraint system, it all adds up to this single term we use, crashworthiness.

(01:16:33:05) ***O'NEILL:*** We use the striped-down body to illustrate the concepts of good and poor structural designs for modern crashworthiness.

(01:16:39:26) ***JONES:*** Brian, why is it important for the vehicle's structure to perform well in a crash?

(01:16:43:17) ***O'NEILL:*** Well, this is what's left of the body and structure of a car that was in a crash and we use this to illustrate the point. Basically we want the occupant compartment, or the safety cage, to remain intact. We don't want any damage or intrusion into this part of the vehicle during the crash.

(01:16:59:07) We want all of the damage of the crash confined to the front end.

(01:17:03:20) ***JONES:*** So even though all this metal looks the same, it's actually different. This, the green metal's intended to crumple, to give in the collision.

(01:17:11:14) ***O'NEILL:*** If we can crumple the front end of the car without allowing any damage to the occupant compartment, then the people inside can be protected against serious injury.

(01:17:21:03) ***O'NEILL:*** Basically we want the front end to be buckling during the crash so that the occupant compartment is slowed down over a gentler rate.

(01:17:28:16) ***JONES:*** Right…kind of like jumping off of a step and keeping your knees straight and landing on the floor versus bending your knees when you land.

(01:17:34:29) ***O'NEILL:*** Exactly the same concept. So this is a vehicle that did well because there's very little intrusion anywhere in the occupant compartment. These elements here, even though they're strong enough to hold an engine and suspension, actually buckled and crushed just like they're designed to do so the damage is confined to the front end.

(01:17:55:00) ***O'NEILL:*** We look at a vehicle like this and this is an example of a very poor safety cage. This vehicle was in a 40 mile-an-hour crash and as you can see, the occupant compartment is collapsed. It's been driven backward. As a result, the driver's space has been greatly reduced, so someone sitting in this vehicle is obviously at a high risk of injury.

(01:18:16:03) ***JONES:*** So even if the restraint systems do function properly - the airbag, the seatbelts - the person is still in great danger.

(01:18:22:13) ***O'NEILL:*** This person in this vehicle, even with a belt system and airbag, is at significant risk of injury because the compartment is collapsing.

(01:18:30:12) ***JONES:*** So it's analogous to shipping a box of china. You can have all the best packing in the world around the china, but if the box is weak, you're going to break the china.

(01:18:38:01) ***O'NEILL:*** When the safety cage collapses, you're going to have injuries to the occupants. So this is an example of poor crashworthiness. But this vehicle was in the same crash…40 miles-an-hour, offset crash, and you can see that now the safety cage has remained intact. There's very little intrusion anywhere. The damage is confined to the crumple zone of the vehicle. This is the way it should be. A person in a crash like this, wearing their seatbelt and protected by the airbag, could walk away from the crash with no injury.

(01:19:09:18) ***JONES:*** Right. If I stand over here, and I just look towards the rear of the car and I ignore the airbag, this doesn't even look like it's been in a crash.

(01:19:18:07) ***O'NEILL:*** That's right. This is good performance, good crashworthiness.

(01:19:21:16) ***JONES:*** In our shipping box analogy, this is an example of a strong box.

(01:19:25:27) ***O'NEILL:*** That's right. The people in this box will be protected.

(01:19:29:15) ***JONES:*** Brian, obviously this car performed well, but what's in the future for crashworthiness?

(01:19:33:26) ***O'NEILL:*** This is an illustration of how good we can do with frontal crashworthiness. But frontal crashes are only part of the problem. We obviously also have to pay attention to other crash modes and one of the most important is the side impact crash.

(01:19:45:17) Now this was a vehicle that was in a severe side impact crash. This vehicle was going 20 miles-an-hour sideways into a pole and as you can see, in a side crash you don't have all the crush space you have in frontal crash. We just have the width of the door and the padding and, in this case, we have an airbag on the inside, which creates even more space. We inflate the airbag to create more crush space. And we also have an inflatable airbag to provide head protection up in this region. This deploys from this roof area here. So the physics are the same, the engineering challenges are greater.

(01:20:27:22) *JONES:* I am always looking for ways to relate the physics that I teach to the real world that my students experience and nothing is more relevant than traveling in an automobile. You probably do it every day. I hope that makes the message of this film important to each and every one of you.

(01:20:43:15) I've always believed that if a person truly understands the laws of physics, that person would never ride in a motor vehicle unbelted and now that you've had a chance to learn some of the finer points of the physics of car crashes, I hope you agree.

(01:20:58:05) I also hope you've learned why some of the choices you make about the type of car you drive, and the kind of driving you do, can make a difference in whether you survive on the highway. Remember, even the best protected race car drivers don't survive very high-speed crashes.

(01:21:12:28) The bottom line is, the dynamics of a motor vehicle crash — what happens to your car and you — is determined by hard science. You can't argue with the laws of physics.

APPENDIX E
CURRICULUM PACKAGE

APPENDIX E-1
VIDEO CONCEPT ORGANIZER

"CRASH COURSE" ACTIVITY

"Understanding Car Crashes It's Basics Physics"
Video Concept Organizer

Teacher Organizer Answers

TIME

Running Time:
22 minutes

Directions:
To help you remember the key physics concepts discussed while viewing the video, fill in the blanks or circle the correct answer

Video Scenes & Key Concepts

Test Track Laws

2:15 Why did the dummy get left behind? It's called inertia, the property of matter that causes it to resist any change in its motion.

2:50 Isaac Newton's (circle one) [✓ 1st] 2nd 3rd Law of Motion states: A body at rest remains at rest unless acted upon by an external force, and a body in motion continues to move at a constant speed in a straight line unless it is acted upon by an external force.

Crashing Dummies

3:20 Now watch what happens when the car crashes into a barrier The front end of the car is crushing and absorbing energy which slows down the rest of the car

4:00 In this case, it is the steering wheel and windshield that applies the force that overcomes the dummy's inertia

Crash-Barrier Chalkboard

4:35 Newton explained the relationship between crash forces and inertia in his (circle one) 1st [✓ 2nd] 3rd Law of Motion

(Fill in the blanks to explain what each letter in the formula represents.)

F = force → $F = ma$

m = mass

a = acceleration

$F = \frac{m\Delta v}{t}$

Δv = change in velocity

t = time or rate

Ft = impulse → $Ft = m\Delta v$

$m\Delta v$ = change in momentum

"CRASH COURSE" ACTIVITY

"Understanding Car Crashes It's Basics Physics"

Video Concept Organizer

Teacher Organizer Answers

TIME

Surfers, Cheetahs, and Elephants ...oh my!

5:20 Momentum is inertia in motion. It is the product of an object's mass and its velocity.

5:35 Which has more momentum? An 80,000 pound big rig traveling 2 mph or a 4,000 pound SUV traveling 40 mph? circle one **Big Rig** **SUV** [✓ **same**]

Soccer Kicks, Slap Shots, and Egg Toss

6:05 What is it that changes an object's momentum? an impulse. It is the product of force and the time for which it acts.

6:18 If the eggs are of equal mass and are thrown at the same velocity they will have the same momenta The wall and the sheet both apply equal impulses.

6:45 The wall applies a bigger force over a shorter time, while the sheet applies a smaller force over a longer time

7:10 With panic braking the driver stops in less time or distance and experiences more force.

Crashing and Smashing

8:20 The second animated vehicle's front end is less stiff so it crushes two feet instead of one, causing the deceleration to decrease from 30gs to 15 gs

9:04 Extending the time of impact is the basis for many of the ideas about keeping people safe in crashes. List three applications in vehicle or highway safety

1. crumple zones 2. airbags 3. break-away light poles

Conserving Momentum and Energy - It's the Law!

9:42 In a collision of two cars of unequal mass, the occupants of the lighter car would experience much higher accelerations, hence much higher forces than the occupants of the heavier car.

12:55 Motion related energy is called kinetic energy Energy due to an object's position or conditions is called potential energy.

13:50 At what point in the pendulum's swing is its potential energy equal to its kinetic energy? mid-point When is its kinetic energy at its maximum? bottom

14:30 Circle the correct formula for kinetic energy (KE)

KE = 1/2 m2v KE = 1/2 2mv² [✓ KE = 1/2 mv²] KE = 1/2 mv2

Name ______________________ Period ______ Date ______

"Understanding Car Crashes It's Basics Physics"
Video Concept Organizer

Student Organizer Questions

TIME

Running Time:
22 minutes

Directions:
To help you remember the key physics concepts discussed while viewing the video, fill in the blanks or circle the correct answer.

Video Scenes & Key Concepts

Test Track Laws

2:15 Why did the dummy get left behind? It's called __________, the property of matter that causes it to______________________________.

2:50 Isaac Newton's (circle one) 1st 2nd 3rd Law of Motion states: A body at rest remains at __________ unless acted upon by an external __________, and a body in __________ continues to move at a constant __________ in a straight line unless it is acted upon by an external force.

Crashing Dummies

3:20 Now watch what happens when the car crashes into a barrier. The front end of the car is crushing and absorbing __________ which slows down the rest of the car.

4:00 In this case, it is the steering wheel and windshield that applies the __________ that overcomes the dummy's __________.

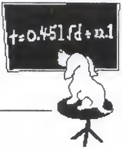
Crash-Barrier Chalkboard

4:35 Newton explained the relationship between crash forces and inertia in his (circle one) 1st 2nd 3rd Law of Motion.
(Fill in the blanks to explain what each letter in the formula represents.)

$F =$ __________ $\rightarrow F = ma$ $m =$ __________
$a =$ __________

$F = \frac{m\Delta v}{t}$ $\Delta v =$
$t =$ ____________________

$Ft =$ __________ $\rightarrow Ft = m\Delta v$ $m\Delta v =$ ____________________



"CRASH COURSE" ACTIVITY

"Understanding Car Crashes It's Basics Physics"
Video Concept Organizer

Student Organizer Questions

TIME

Surfers, Cheetahs, and Elephants ...oh my!

5:20 Momentum is ____________ in motion. It is the product of an object's ____________ and its ____________.

5:35 Which has more momentum? An 80,000 pound big rig traveling 2 mph or a 4,000 pound SUV traveling 40 mph? circle one Big Rig SUV same

Soccer Kicks, Slap Shots, and Egg Toss

6:05 What is it that changes an object's momentum? ____________. It is the product of ____________ and the ____________ for which it acts.

6:13 If the eggs are of equal mass and are thrown at the same velocity they will have the same ____________. The wall and the sheet both apply equal ____________.

6:45 The wall applies a ____________ force over a ____________ time, while the sheet applies a ____________ force over a ____________ time.

7:10 With panic braking the driver stops in less time or distance and experiences more ____________.

Crashing and Smashing

8:20 The second animated vehicle's front end is less stiff so it crushes two feet instead of one, causing the deceleration to ____________.

9:04 Extending the time of impact is the basis for many of the ideas about keeping people safe in crashes. List three applications in vehicle or highway safety.

1.____________ 2.____________ 3.____________

Conserving Momentum and Energy–it's the Law!

9:42 In a collision of two cars of unequal mass, the occupants of the lighter car would experience much higher ____________, hence much higher ____________ than the occupants of the heavier car.

12:55 Motion related energy is called ____________. Energy due to an object's position or conditions is called ____________.

13:50 At what point in the pendulum's swing is its potential energy equal to its kinetic energy? ____________ When is its kinetic energy at its maximum? ____________

14:30 Circle the correct formula for kinetic energy (KE).

KE = 1/2 m2v KE = 1/2 2mv^2 KE = 1/2 mv^2 KE = 1/2 mv2

APPENDIX E-2
POST-VIDEO DISCUSSION QUESTIONS

"CRASH COURSE" ACTIVITY

"Understanding Car Crashes It's Basics Physics"

Video Discussion Questions

Teacher
Post-Video
Answers

Directions:

After viewing the video, answer the following questions in the space provided. Be prepared to discuss your responses with your classmates while in small groups or as an entire class

Post-Video "Crash" Questions

1. Ever tried to stop a 150 pound (68 kg) cannonball fired towards you at 30 mph (48 km/hr.)? No, probably not. But you may have tried to brace yourself in a car collision. How are the two situations similar?

   Both you and the cannonball have momentum based upon mass and velocity. If you are traveling 30 mph and weigh 150 pounds your momentum would equal the cannonball's. In a major collision, it is impossible to prevent injuries by bracing yourself. No matter how strong you think you are, you are not strong enough to stop your inertia during a collision.

2. Show mathematically why an 80,000 pound (36,000 kg) big rig traveling 2 mph (0.89 m/s) has the SAME MOMENTUM as a 4,000 pound (1,800 kg) sport utility vehicle traveling 40 mph (18 m/s).

   Momentum is the product of an object's mass and velocity. The formula is $p = mv$. The product of each is equivalent.

   The SI unit for momentum is the kilogram x meter/second (kg x m/s).

   Truck momentum = (36,000 kg)(0.89 m/s) = 32,000 kg x m/s

   SUV momentum= (1,800 kg)(18 m/s) = 32,000 kg x m/s

3. During the Egg-Throwing Demonstration, which egg experienced the greater impulse, the egg that hit the wall or the bed sheet? (Be careful here!) Which egg experienced the greater force of impact? Which egg experienced the greater time of impact?

   If their momenta are equal before the collisions (same mass and velocity), both eggs experience identical impulses because both are stopped by the collision.

   The egg that hit the crash barrier experienced the greater impact force due to the shorter impact time.

   The egg that collided with the bed sheet experienced the greater time of impact, thereby experiencing a smaller stopping force over a longer time interval.

"CRASH COURSE" ACTIVITY

"Understanding Car Crashes It's Basics Physics"

Video Discussion Questions

Teacher Post-Video Answers

4. Explain how the fortunate race car drivers survived their high speed accidents.

   The impulse that the wall applied to both cars was identical BUT remember impulse is the force of impact multiplied by the time of impact. With the fortunate driver, the identical impulse was a product of a small force extended over a long period of time.

5. Describe other examples where momentum is reduced by applying a smaller collision force over a longer impact time (or where things "give way" during a collision to lessen the impact force)?

   Answers will vary. Some examples: Bungee jumping; trampolines; trapeze safety nets; falling on grass compared to concrete; many football players prefer the "give" of natural grass to the harder artificial turf.

6. Which would be more damaging to your car, having a head-on collision with an identical car traveling at an identical speed or driving head on into the Vehicle Research Center's 320,000 pound (145,455 kg) deformable crash barrier? Explain.

   Both crashes produce the same result. Either way the car rapidly decelerates to a stop. In a head-on crash of identical cars travelling at equal speeds, the result is equal impact forces and impact times (according to Newton's Third Law of Motion), and therefore equal changes in momenta. Using a crash barrier is more cost efficient.

7. Show mathematically why a small increase in your vehicle's speed results in a tremendous increase in your vehicle's kinetic energy. (For example, doubling your speed from 30 mph to 60 mph results in a quadrupling of your kinetic energy.)

   The velocity is squared in the equation; therefore if the speed is first doubled then squared, its kinetic energy must quadruple to keep the equation balanced.

   $KE = 1/2\ mv^2 \qquad 4KE = 1/2\ m2v^2$

8. The Law of Conservation of Energy states: energy cannot be created or destroyed; it can be transformed from one form to another but the total amount of energy never changes. Car crashes can involve huge amounts of energy. How does the crashworthiness of the car affect the transfer and transformations of the energy and, ultimately, protect the occupants?

   In a crash of a well designed car, the kinetic energy does the work that crushes the car's crumple zones. Some of the energy also becomes heat and sound generated by the crash. The safety cage must be strong enough to resist the forces that arise during the crash so that it holds its shape and allows the restraint system to do its job.

Name ______________________ Period ______ Date ______

"Understanding Car Crashes It's Basics Physics"
Video Discussion Questions

Student Post-Video Questions

Directions:
After viewing the video, answer the following questions in the space provided. Be prepared to discuss your responses with your classmates while in small groups or as an entire class.

Post-Video "Crash" Questions

1. Ever tried to stop a 150 pound (68 kg) cannonball fired towards you at 30 mph (48 km/hr.)? No, probably not. But you may have tried to brace yourself in a car collision. How are the two situations similar?

2. Show mathematically why an 80,000 pound (36,000 kg) big rig traveling 2 mph (0.89 m/s) has the SAME MOMENTUM as a 4,000 pound (1,800 kg) sport utility vehicle traveling 40 mph (18 m/s).

3. During the Egg-Throwing Demonstration, which egg experienced the greater impulse, the egg that hit the wall or the bed sheet? (Be careful here!) Which egg experienced the greater force of impact? Which egg experienced the greater time of impact?

"CRASH COURSE" ACTIVITY

"Understanding Car Crashes It's Basics Physics"
Video Discussion Questions

Student Post-Video Questions

4 Explain how the fortunate race car drivers survived their high speed crashes.

5 Describe other examples where momentum is reduced by applying a smaller collision force over a longer impact time (or where things "give way" during a collision to lessen the impact force)?

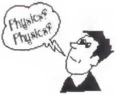
6 Which would be more damaging to your car: having a head-on collision with an identical car traveling at an identical speed or driving head on into the Vehicle Research Center's 320,000 pound (145,455 kg) deformable concrete crash barrier? Explain.

Name ______________________ Period ______ Date ______

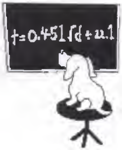
"Understanding Car Crashes It's Basics Physics"
Video Discussion Questions

Student Post-Video Questions

7 Show mathematically why a small increase in your vehicle's speed results in a tremendous increase in your vehicle's kinetic energy. (For example: doubling your speed from 30 mph to 60 mph results in a quadrupling of your kinetic energy.)


Physics?
Physics?

8 The Law of Conservation of Energy states: energy cannot be created or destroyed; it can be transformed from one form to another but the total amount of energy never changes. Car crashes can involve huge amounts of energy. How does the crashworthiness of the car affect the transfer and transformations of the energy and, ultimately, protect the occupants?



APPENDIX E-3
HANDS-ON SCIENCE ACTIVITIES

"CRASH COURSE" ACTIVITY

Penny for Your Thoughts on Inertia

TEACHER LESSON 1

Crash Course Definitions

inertia: property of an object to resist any change in its state of motion

mass: quantity of matter in an object; measure of an object's inertia

Key Question(s)

- How do magicians pull a tablecloth out from under an entire set of dishes? Is it magic or science?
- How is a magician's tablecloth trick related to a crash dummy falling off the tailgate of a pickup truck as the truck accelerates?

Grade levels: 9–12

Time required: 5–10 minutes

Objectives

Students will.

- learn and apply Newton's First Law of Motion
- recognize inertial mass as a physical property of matter

National Science Education Standards

Standard A. Science as Inquiry
- Identify questions and concepts that guide scientific investigations

Standard B: Physical Science
- Motion and forces

Standard G: History & Nature of Science
- Science as a human endeavor
- Historical perspectives

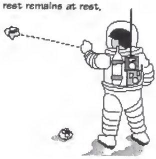
Background Information

The origins of **Newton's Laws of Motion** began with the Italian philosopher Galileo Galilei (1564–1642). Galileo broke from the teachings of Aristotle that had been accepted as truth for more than 1,000 years. Where Aristotle and his followers believed moving objects must be steadily pushed or pulled to keep moving, Galileo showed with his experiments that moving things, once moving, continued in motion without being pushed or pulled (forces applied). He called the property of objects to behave this way **inertia**, which is Latin for "lazy" or "inert."

Isaac Newton, born in England on Christmas day in 1642 (the year Galileo died) refined Galileo's Principle of Inertia in terms of unbalanced forces and made it his first law of motion

Newton's First Law of Motion

In the absence of an unbalanced force, an object at rest remains at rest, and an object already in motion remains in motion at constant speed on a straight line path.



"CRASH COURSE" ACTIVITY

Penny for Your Thoughts on Inertia

TEACHER LESSON 1

Materials needed

For each group

- 3"x 5" index card
- plastic cup or beaker
- 1–10 pennies
- (optional) mix of dimes, nickels, quarters, half dollars

Getting ready

Assemble the materials for each group You may wish to consider having other coins available for the groups to try Their results may vary with the mass of the coins used. More mass results in more inertia.

Procedure

1. Cover the cup with the index card and put the penny on top of the card.
2. Challenge the students to get the penny in the cup without lifting the card and only touching it with one finger.

   Best method "Flick" the card horizontally with your forefinger

3. After students have succeeded with one penny, challenge them to try multiple pennies and other coins

Answers to analysis questions

1. Describe a successful technique.

   Answers will vary. See above for best method, Step 2 Procedure.

2. Why does the penny drop in the cup when the card is "flicked" away? **Very little of the sudden horizontal force from your flicking finger is transferred upward to the penny, so the inertia of the penny keeps it over the mouth of the cup. With the card no longer providing support force, the force of gravity pulls it straight down into the cup.**

3. How did the total mass of the coins used affect your success?

   They should have been more successful with more mass. More mass equals more inertia, which equates to a greater resistance to movement. But too much mass increases the force of friction beyond your horizontal flicking force and the card cannot move out from under the coins.

4. How do magicians use Newton's First Law to their advantage in pulling a tablecloth out from under an entire set of dishes?

   The heavier the plates the greater the inertia, and the better the magician's chance for success. But too much mass increases the force of friction beyond the horizontal pulling force and the tablecloth cannot move out from under the dishes.

Answers to crash questions

How is a magician's tablecloth trick related to a crash dummy falling off the tailgate of a pickup truck as the truck accelerates?

Both apply the concept of inertia. Just as inertia keeps the plates at rest as the magician pulls the tablecloth our from under them, inertia keeps the crash dummy at rest as the tailgate moves out from under it.

Name ______________________ Period ______ Date ______

STUDENT ACTIVITY 1

Penny for Your Thoughts on Inertia

Crash test question

- How is a magician's tablecloth trick related to a crash dummy falling off the tailgate of a pickup truck as the truck accelerates?

Purpose

To explore the concept of inertia.

Materials needed

For each group:

- 3"x 5" index card
- plastic cup or beaker
- 1–10 pennies
- (optional) mix of dimes, nickels, quarters, half dollars

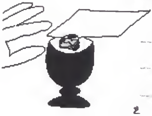
Discussion

Whether you are attempting the magician's tablecloth trick or slamming on your car brakes to avoid an accident, the laws of nature apply. Understanding nature's basic rules or PHYSICS can help improve your chances of success in either situation.

Procedure

1. Cover the cup with the index card and put the penny on top of the card.
2. The challenge is to get the penny into the cup without lifting the card and only touching the card with one finger.
3. After you have succeeded with one penny, try it with multiple pennies and other coins.

Analysis



1. Describe a successful technique.

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2. Why does the penny drop in the cup when the card is "flicked" away?

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Penny for Your Thoughts on Inertia

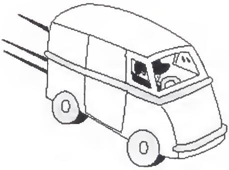
STUDENT ACTIVITY 1

3 How did the total mass of the coins affect your success?

4 How is a magician's tablecloth trick related to a crash dummy falling off the tailgate of a pickup truck as the truck accelerates?

Crash question

How are the magician's tablecloth trick and vehicle seat belts related?



"CRASH COURSE" ACTIVITY

Momentum Bashing

TEACHER LESSON
2

Crash Course Definitions

momentum: the product of the mass and the velocity of an object (p = mv)

velocity: the speed of an object and its direction of motion

acceleration: the rate at which velocity is changing

Key question(s)

- What determines if one car has more momentum than another in a two-car collision?
- Does increasing an object's mass increase its momentum or "bashing power?"

Grade levels: 9–12
Time required: 15–20 minutes

Objectives

Students will.

- understand and apply the definition of momentum: **momentum = mass x velocity**
- conduct semi-quantitative analyses of the momentum of two objects involved in one-dimensional collisions
- describe automobile technologies that reduce the risk of injury in a collision

National Science Education Standards

Standard A. Science as Inquiry

- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations

Standard B: Physical Science

- Motion and forces
- Conservation of energy

Standard F. Science in Personal and Social Perspectives

- Natural and human-induced hazards

Standard G: Nature of Science

- Nature of scientific knowledge
- Historical perspectives

Background Information

Science is a process that is performed not only by individuals but by a "scientific community." One of the first groups to represent the scientific community was the Royal Society of London for Improving Natural Knowledge, founded in 1660. The group evolved from informal meetings where the members discussed and performed simple scientific experiments. Led by a soon-to-be-famous member named Isaac Newton, they began to explore the topic of motion and collisions. Drawing on previous work from the "scientific community" and his own observations, Newton deduced his three simple laws of motion

Newton's Second Law of Motion states that if you wish to accelerate something, you must apply a force to it. **Newton's First Law of Motion** then says, once an object is moving it will remain moving (unless friction or another outside force, like a wall, stops it). This is inertia of motion, or **momentum**

The momentum of a moving object is related to its mass and velocity. A moving object has a large momentum if it has a large mass, a large velocity, or both. A marble can be stopped more easily than a bowling ball. Both balls have momentum. However, the bowling ball

"CRASH COURSE" ACTIVITY

Momentum Bashing

TEACHER LESSON 2

has more momentum than a marble. Momentum changes if the velocity and/or mass changes. (For more on momentum see background information from Lesson #4.)

Materials needed

For each group.

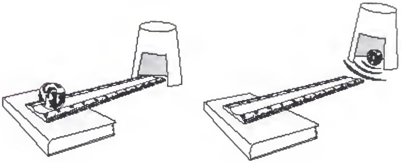
- ruler with center groove
- 4 marbles, same size
- 5-ounce (148 ml) paper cup
- scissors
- meter sticks (2)
- book to support track (3–4 cm height)

Procedure

1. Explain how scientific knowledge changes by evolving over time, almost always building on earlier knowledge (refer to background information). Tell students this lesson builds on their knowledge of force, inertia, and speed to better understand what happens in a crash. Begin the activity with a discussion of the following open-ended questions on momentum.
   - Momentum is often used by sports commentators or political analysts to describe a team's or candidate's performance, yet in physics it has a specific meaning. Can they explain the difference?
   - What determines if one car has more momentum than another in a two-car collision?
2. Explain that momentum has often been loosely defined as the amount of "oomph" or "bashing power" of a moving object. It is the measurement of an object's inertia in motion or more specifically,

   momentum = mass x velocity

   In this activity students will see how an object's mass affects its "oomph" or "bashing power."
3. Distribute "Momentum Bashing" activity sheets and supplies to each group. Instruct each group to cut the section from their paper cup and set up their ramp. Long flat tables or tile floors work well for this activity.



"CRASH COURSE" ACTIVITY

Momentum Bashing

TEACHER LESSON 2

4. Circulate and assist groups. Have students measure the distance the cup moves to the nearest 0.1 cm With good techniques, this simple equipment can produce results that are consistent enough to have students conclude that increasing the number of marbles increases the bashing power or momentum (see sample data).

number of marbles	trial 1 cm	trial 2 cm	trial 3 cm
1	5.0	5.0	5.7
2	12.5	13.0	12.5
3	19.5	19.2	19.0
4	24.0	24.1	24.8

sample data for distance cup moves (with ruler height 3.0 cm)

Answers to analysis questions

1. Describe the relationship between the number of marbles hitting the cup and the distance the cup moves.
   As the number of marbles increase the distance the cup moves increases. The average increase in distance was 6.8 cm, 6.5, and 5.8 for each additional marble: 1–2, 2–3, 3–4 respectively.

Answers to crash questions

1. What determines if one car has more momentum than another in a two-car collision?
   Momentum is a product of a car's mass and velocity. A lighter car can have a greater momentum if it has a high speed compared with the heavier car.
2. Explain why an 80,000 pound big rig traveling 2 mph has the same momentum as a 4,000 pound sport utility vehicle (SUV) traveling 40 mph.
   Since momentum is the product of mass and velocity, the truck's large mass and slow speed is matched by the SUV's smaller mass but greater speed.

momentum = mass x velocity

$$p = mv$$

Big Rig's momentum = SUV's momentum

$$mv = mv$$

$$(80{,}000 \text{ lbs.})(2 \text{ mph}) = (4{,}000 \text{ lbs.})(40 \text{ mph})$$

Extension(s)

1. Have students conduct further experiments with the same equipment by investigating the relationship between the height of the ruler and the distance the cup is moved. The greater release height increases the marbles' potential energy, thereby increasing their kinetic energy, speed, and momentum upon impact with the cup.
2. Have students discover the Law of Conservation of Momentum by exploring the results of two colliding objects. (See Student Activity #4).

Name ____________________________ Period ______ Date ______

Momentum Bashing

STUDENT ACTIVITY 2

Crash test question(s)

- What determines if one car has more momentum than another in a two-car collision?
- Does increasing an object's mass increase its momentum?

Purpose

- To determine if increasing mass increases momentum
- To describe automobile technologies that reduce the risk of injury in a collision

Materials needed

For each group:

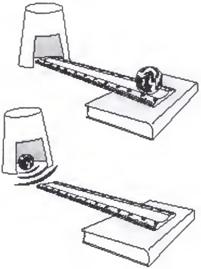
- ruler with center groove
- 4 marbles, same size
- 5-ounce (148 ml) paper cup
- scissors
- meter sticks (2)
- book to support track (3–4 cm height)

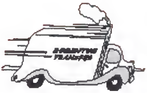
Discussion

To better understand what happens in a crash, it helps to see how force, inertia, and speed are related in a property called momentum. The amount of momentum, often referred to as "oomph" or "bashing power," that an object has depends on its mass and its velocity. In this activity you will investigate how an object's mass affects its "bashing power!"

Procedure

1. Cut a 3.0 cm square section from the top of the paper cup.
2. Place the ruler with one end on a textbook (approximately 3.0 cm height) and the other end resting on the desk.
3. Place the 3.0 sq. cm opening of the cup over the end of the ruler resting on the desk.
4. Place a meter stick along side the cup to measure the distance it moves.
5. Position ONE (1) marble in the groove at the ruler's maximum height.





"CRASH COURSE" ACTIVITY

Momentum Bashing

STUDENT ACTIVITY 2

6. Release the marble and observe the cup.
7. Measure the **distance** the cup moved (to the nearest 0.1 cm).
8. Perform three (3) trials for 1, 2, 3, and 4 marbles and average the results. **Record** these measurements in the data table below.

number of marbles	measured distance cup moves (cm)			average distance cup moves (cm)
	trial 1	trial 2	trial 3	
1				
2				
3				
4				

Analysis

1. Describe the relationship between the number of marbles hitting the cup and the distance the cup moves.

Crash questions:

1. What determines if one car has more momentum than another in a two-car collision?
2. Explain why an 80,000 pound big rig traveling 2 mph has the same momentum as a 4,000 pound sport utility vehicle (SUV) traveling 40 mph.

"CRASH COURSE" ACTIVITY

Egg Crash! Designing a Collision Safety Device

TEACHER LESSON 3

Key question(s)

- How do people survive major collisions?
- How does physics explain the effectiveness of seat belts and airbags?

Grade levels: 9–12

Time required: 50 minutes

Crash Course Definitions

Impulse: product of force and time interval during which the force acts, impulse equals change in momentum, $F\Delta t=\Delta(mv)$

Impact: qualitative term for force

Objectives

Students will.

- describe a collision in terms of momentum changes and impulse
- design, build, test, and evaluate a safety device to protect an egg during a collision

National Science Education Standards

Standard A. Science as Inquiry
- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations

Standard B Physical Science
- Motion and forces

Standard E Science and Technology
- Abilities of technological design
- Understanding about science and technology

Standard F: Science in Personal and Social Perspectives
- Natural and human-induced hazards

Background Information

When Newton described the relationship between force and inertia, he spoke in terms of two other physics concepts: momentum and impulse. Newton defined momentum as the product of an object's mass and velocity (see Lesson #2). Newton defined impulse as the quantity needed to change an object's momentum

To change an object's momentum either the mass or the velocity or both change. If the mass remains constant, then the velocity changes and acceleration occurs. In his second law, Newton said in order to accelerate (or decelerate) a mass, a force must be applied. The way it's often expressed is with the equation **F=ma.** The force "F" is what's needed to move mass "m" with an acceleration "a." The greater the force on an object, the greater its acceleration, or the greater its change in velocity, and therefore, the greater its change in momentum. How long the force acts is also important. Apply the brakes briefly to a coasting car and you produce a change in its momentum. Apply the same braking force over an extended period of time and you produce a greater change in the car's momentum. So to change something's momentum both force and time are important. The product of force and the time it is applied is called **Impulse**.

Impulse = force x time interval

"CRASH COURSE" ACTIVITY

Egg Crash! Designing a Collision Safety Device

TEACHER LESSON 3

The greater the impulse exerted on an object, the greater its change in momentum The amount of damage in a collision is related to the time during which the force stopped the object. Seat belts and airbags stop occupants with less damage by applying a small force over a large time interval.

Materials needed

For each group
- copier paper, 10 sheets (8 1/2"x11")
- masking tape, 1.0 meter
- scissors, one pair

For the Egg-Crash Tests:

- eggs, one raw, grade A, medium or large egg per team (1–2 dozen)
- newspaper, 15–20 sheets
- meter sticks, (2–3)
- ladder, 2 meters tall (approx. 6 ft.)
- hard-surfaced floor, walkway, or playing surface (e.g. basketball court)

Getting ready

Separate paper into stacks of 10 sheets each. Prepare a "crash site" to test students' projects by spreading newspaper on the floor to cover an area approximately one square meter. Place a ladder next to the "crash site."

Procedure

1. Ask students to think about how people survive major vehicle collisions. Explain that scientists and engineers apply the laws of physics to reduce damage to both cars and passengers. Explain that during this activity, students will be working in groups to design, build, test, and evaluate a "safety device" (in the form of a landing pad) to protect a raw egg during a collision with a hard surface (floor).
2. Divide students into groups of two or three and distribute paper (10 sheets per group), masking tape (1 meter per group) and scissors to each group.
3. Review "Collision Safety Device" or landing pad design, building, and testing parameters with students (see "Egg Crash!" Student Activity Sheet #3). Remind students that their device must protect the egg from repeated collisions, with each experiencing a greater change in momentum.
4. Allow students 20 minutes to build their devices. Distribute eggs to students after the time limit has expired. Do not allow any pre-testing of devices.

Hmmm...I wonder if...

"CRASH COURSE" ACTIVITY

Egg Crash! Designing a Collision Safety Device

TEACHER LESSON 3

5. Determine the order in which teams are to drop or ask for teams to volunteer. Complete drops for round one before beginning round two with surviving eggs. **Suggested drop heights for rounds: 1.0 m, 1.5 m, 2.0 m, 2.5 m.**
6. Before beginning the final round, conduct a brief whole-class discussion addressing the following questions.
   - Which device do you predict to win and why? **Answers will vary. Challenge students to relate the functioning of the devices to similar situation from their prior experience. Students may refer to interactions in which one object has more "give" than another. For example: falling on grass rather than concrete; or, when jumping from an elevated position down to the ground, bending your knees when your feet make contact with the ground instead of keeping your legs straight.**
   - Why does a surface with more "give," like their Collision Safety Device, produce a safer fall? **To bring the egg to a stop, the floor or the paper device must provide an impulse, which involves two variables—impact force and impact time. Since impact time is longer on the paper device, a smaller impact force results. The shorter impact time on the floor results in a greater impact force.**
7. After the superior Collision Safety Device has been determined, have students complete the Analysis and Crash Questions.

Answers to crash questions

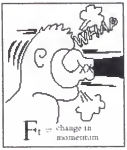
1. Explain how your Collision Safety Device is similar to an airbag in preventing injuries. Use the terms momentum, impulse, impact force, and impact time in your response. **To bring the egg to a stop, the paper device must change the egg's momentum by providing an impulse, which involves two variables —impact force and impact time. Since impact time is longer on the paper device, a smaller impact force results. The shorter impact time on the floor results in a greater impact force. Airbags stop occupants with less damage by applying a small force over a large time interval.**
2. Compare the impulses, impact forces, and impact times of the following: Race Car #1 crashes to a stop by hitting a wall head on; Race Car #2 crashes to a stop by skidding a great distance along a wall. **Assuming both cars have equal momentum before the crash, both race cars experience the SAME impulse or change in momentum since they both crash to a stop. Race Car #1 experiences a big impact force over a short impact time. Race Car #2 experiences small impact force over a longer time of impact.**

"CRASH COURSE" ACTIVITY

Egg Crash! Designing a Collision Safety Device

TEACHER LESSON
3

3. List other vehicle safety devices that reduce the impact force by increasing the time of impact.
   frontal crumple zones, padded dashboards, bumpers, collapsible steering columns
4. According to the National Highway Traffic Safety Administration thousands of people are alive today because of their airbags. Explain why airbags are NOT alternatives to seat belts but rather are intended to be used WITH seat belts to increase safety.
   Designed to work with seat belts, airbags provide additional protection, especially to people's heads and chests, in serious crashes. If there is hard braking or other violent maneuvers before the crash, the lap/shoulder belts keep people in position where there is still space for the airbags to inflate between the occupants and the hard interior surfaces. Belts also provide important protection in nonfrontal crashes. According to the Insurance Institute for Highway Safety, deaths in frontal crashes of cars with airbags are reduced by about 26 percent among drivers and 14 percent among passengers.



Extension(s)

1. Have students explore the Insurance Institute for Highway Safety's website (www.highwaysafety.org) to answer the following questions about airbags.
   - How serious does a frontal crash have to be for an airbag to inflate?
   - Are there any problems with airbags?
   - Can they injure people? How? Who is at greatest risk?
   - Should people at risk get an on/off switch for their airbags?
2. Have students videotape (either live or from television), explain, and present sequences that illustrate various interactions that effectively reduce the force by increasing the time.

Possible Interactions:

- bungee jumping
- circus trapeze safety net
- boxing match (see Figure 1)
- egg toss into a bed sheet (see video, have two students hold a sagging bed sheet while another student throws an egg into the sheet)
- egg toss game (wearing lab aprons and safety goggles, pairs of students toss eggs back and forth at successively greater distances; unbroken egg caught at greatest distance wins Note: record for Mr. Jones' classes is 31 m.)

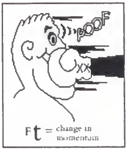


figure 1

Name __________________________Period_______ Date_______

Egg Crash! Designing a Collision Safety Device

STUDENT ACTIVITY 3

Crash test question(s)

- How do people survive major collisions?
- How does physics explain the effectiveness of seat belts and airbags?

Purpose

- To design, build, test, and evaluate a landing pad or "safety device" to protect an egg during a collision with a hard surface
- To describe a collision in terms of changing momentum, impulse, impact force, and impact time

Materials needed

For each groups of two or three students:

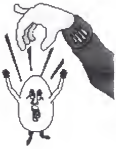
- copier paper, 10 sheets (8 1/2" x 11")
- masking tape, 1.0 meter
- scissors, one pair

Discussion

How do people survive major vehicle collisions? Scientists and engineers apply the laws of physics to reduce damage to both cars and passengers. During this activity, you will work in groups to design, build, test, and evaluate a "collision safety device" (in the form of a landing pad) to protect a raw egg during a collision with a hard surface. Hopefully, this process will help you discover the physics underlying some of the "EGGcellent" safety devices in a car!

Procedure

Using no more than 10 sheets of paper, one meter of masking tape and following the parameters listed on the back of this sheet, design, build, and test a landing pad/"collision safety device" that will protect an egg when dropped from ever increasing heights.



"CRASH COURSE" ACTIVITY

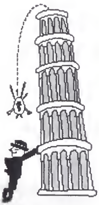
Egg Crash! Designing a Collision Safety Device

STUDENT ACTIVITY

3

EGG "Collision Safety Device" Parameters

1. Groups may use less, but no more than 10 sheets of paper.
   - Report to the teacher the amount of paper used to build your safety device. In the event of a tie, the device constructed with fewest sheets of paper will be declared the superior safety device.
2. Collision Safety Devices must be free-standing. Teams cannot support their devices by holding them or taping them to another structure.
3. Nothing may be attached to the egg.
4. Scissors may not be part of the Collision Safety Device
5. Dropping height is measured from the bottom of the egg, at the release point, to the top of the Collision Safety Device.
6. Eggs will be dropped by a member of the Device's design team.
7. Eggs that miss the Collision Safety Device when dropped are eliminated.
8. Eggs will be inspected before and after each drop and must not show any cracks
   - Eggs that survive the initial impact but roll off their device and break are eliminated.
   - Teams that break their egg by accident or carelessness are eliminated.
9. In order to simulate car collisions with greater momentum the eggs will be dropped from successively greater heights (1.0 m, 1.5 m, 2.0 m, 2.5 m)
10. Devices must be completed within the time limit of 20 minutes.



Name ______________________ Period ______ Date______

STUDENT ACTIVITY 3

Egg Crash! Designing a Collision Safety Device

Analysis

1. Draw a large diagram of your Collision Safety Device in the space below.

2. Describe your team's Collision Safety Device, the reasoning behind your design, and its performance during the various collisions. Refer to your diagram.

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Crash questions

1. Explain how your Collision Safety Device is similar to an airbag in preventing injuries. Use the terms momentum impulse, impact force, and impact time in your response.

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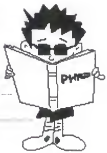


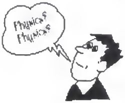
"CRASH COURSE" ACTIVITY

Egg Crash! Designing a Collision Safety Device

STUDENT ACTIVITY 3

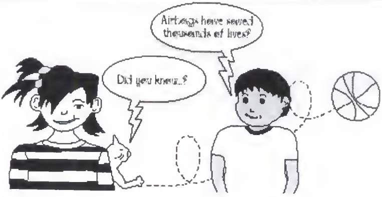
More crash questions

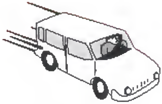
2 Compare the impulses, impact forces, and impact times of the following: Race Car #1 crashes to a stop by hitting a wall head on; Race Car #2 crashes to a stop by skidding a great distance along a wall.


Physics! Physics!

3 List other vehicle safety devices that reduce the impact force by increasing the time of impact.

4 Explain why airbags are **not** alternatives to seat belts but are intended to be used with seat belts to increase safety.


Airbags have saved thousands of lives!
Did you know...?



"CRASH COURSE" ACTIVITY

Conservation: It's the Law!

TEACHER LESSON 4

Crash Course Definitions

energy: the ability to do work, "the stuff" that makes things move

work: the ability to apply a force (push or pull) over a distance, W = F x d

vector quantity: a quantity in physics, such as force, that has both magnitude and direction

scalar quantity: a quantity in physics, such as mass, that can be completely specified by its magnitude; it has no direction

Key question(s)

- Are bigger, more massive cars safer?
- Where does the energy "go" during a collision?

Grade levels: 9–12
Time required: 30–40 minutes

Objectives

Students will:

- describe a collision in terms of momentum and energy
- predict the relationship between energy and velocity of colliding objects
- infer how the law of conservation of momentum is applied in collisions
- infer how the law of conservation of energy is applied in collisions

National Science Education Standards

Standard A: Science as Inquiry

- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations

Standard B: Physical Science

- Motion and forces
- Conservation of energy

Standard E: Science and Technology

- Understanding about science and technology

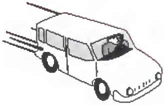
Standard F: Science in Personal and Social Perspectives

- Natural and human-induced hazards

Background Information

Car collisions can illustrate and help students discover the concept of energy. Energy is defined as the ability to do work. And work is the ability to apply a force (push or pull) over a distance.

All energy can be considered either kinetic energy, which is the energy of motion, potential energy, which is stored energy due to its relative position or condition; or energy contained by a field, such as light or radio waves. Underlying every car crash are two conservation laws of physics: the law of conservation of energy and the law of conservation of momentum. The conservation of energy law states that energy cannot be created or destroyed; it may be transformed from one form to another, but the total amount of energy never changes. The conservation of momentum law states that the total quantity of momentum of a group of objects does not change unless acted on by an outside force



"CRASH COURSE" ACTIVITY

Conservation: It's the Law!

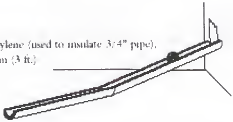
TEACHER LESSON 4

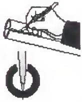
Like energy, momentum can transfer from one object to another. **Newton's Third Law of Motion** describes how all forces occur in equal pairs but in opposing directions. Consider a marble rolling along a track and hitting a motionless but identical marble. Upon colliding each marble experiences the same force but in opposite directions. The force of the first ball transfers to the second. Along with a transfer of forces is a transfer of momentum. Since both balls experience the same amount of force at the same time, the transfer is equal. What one marble loses in momentum the other ball gains (and the system's total momentum is unchanged). This observable phenomenon of maintaining and transferring momentum equally is called the **law of conservation of momentum.**

Momentum is a vector quantity, which means the direction it is traveling is also important. Vector quantities can cancel out if they are of the same magnitude but in opposite directions! Energy is not a vector quantity, it cannot be canceled, it must go somewhere! In a crash of a well-designed car, crash energy does the work that crushes the car's crumple zones. Some of the energy also becomes heat and sound generated by the crash.

Materials needed

For each group of two students:
- 7 marbles, same size
- pipe insulation, 3/8" tubular polyethylene (used to insulate 3/4" pipe), without adhesive, cut length to 92 cm (3 ft.)
- masking tape, 30 cm
- meter stick
- books to support track (3–5)



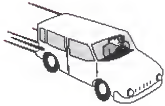


Getting ready

Pipe insulation can be purchased from large home supply stores for less than one dollar a section. The pipe insulation must be split down the middle and cut to create two open-faced, 6-foot rollways. Cut the rollways into 92cm (3 ft) length sections.

Procedure

1. Inform students that they are going to investigate the relationship between forces, motion, and energy. Divide students into pairs and distribute the supplies and student activity sheets, "Conservation: It's the Law!"
2. Have students set up the track as described and pictured on the Student Activity sheet. Tell students to test the track for a straight alignment by rolling a marble along the entire length of the track. If necessary, have students straighten and retape the track.
3. Briefly review the data tables and the procedure for completing the activity sheet.
4. Have students discover the relationships as you guide the lesson. Conduct a whole-class discussion addressing the Analysis and Crash Questions.



"CRASH COURSE" ACTIVITY

Conservation: It's the Law!

TEACHER LESSON

4

Answers to analysis questions:

1. Describe your results from Data Table #1

   For all release heights, the number of released marbles equals the number of marbles knocked away from the row.

2. Describe your results from Data Table #2.

   The greater the release height, the greater the marble's speed before the collision. The speed of the released marble(s) before impact equals the speed of the marble(s) knocked away.

3. How does the height of release affect the marbles' energy and momentum?

   The greater the release height, the greater the marble's potential energy. When released, its potential energy transforms to kinetic energy. The greater the kinetic energy, the greater the marble's velocity and momentum. Momentum is the product of mass and velocity, $p = mv$.

4. What conclusions can you make from Data Table #1 regarding the energy of the released marble(s) and the energy of the marble(s) knocked away from the row?

   The energy before the collision equals the energy after the collision.

5. What conclusions can you make from Data Table #2 regarding the momentum of the released marble(s) and the momentum of the marble(s) knocked away from the row?

   The momentum before the collision equals the momentum after the collision.

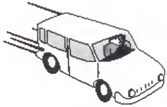
Answers to crash questions

1. Describe the collision pictured below in terms of momentum, if the truck has four times the momentum of the car before the collision.

   With more momentum, the truck will keep going in its original direction and snap the car into sudden reverse. There is an equal change in momentum, but in opposite directions. Each experiences the same change in momentum but with differing effects due to their initial momenta. The truck had more momentum initially so the change is less noticeable; it continues in the same direction but at a reduced speed. The total momentum of both vehicles before the collision is equal to the total momentum after the collision.

2. Describe the collision pictured below in terms of energy, if the truck has four times the energy of the car before the collision.

   Unlike momentum, kinetic energy is a non-vector or scalar quantity and cannot be canceled. The energies add up, resulting in over four times the deformation and heat after the collision. Energies transform to other forms; momenta do not.



"CRASH COURSE" ACTIVITY

Conservation: It's the Law!

TEACHER LESSON 4

Additional crash questions

1. Use the following questions to further assess the students' conceptual knowledge.
   - What is the physics term used to describe how difficult it is to stop a moving object? **(Inertia in motion or momentum, calculated by mass x velocity = momentum; see "Activity #2: Momentum Bashing")**
   - How about head-on collisions with cars of the same speed but different masses? Let's say your heavy car is hit by a lighter car. What happens to your car? ***Your car is more massive therefore it has more momentum than the lighter car. When the cars collide, your heavier car would keep going in its original direction.***
   - Now, what if your car is hit by a heavier car? ***The heavier car would drive your car backward during the crash. For example, if both cars were traveling at 30 mph and the heavier car had twice the mass of your car, then the passenger compartment of your lighter car would be decelerated from 30 mph to 0 mph and then accelerated backward to 10 mph. The speed change would be 40 mph for the lighter car, but the heavier car would experience a speed change of only 20 mph. Your lighter car causes you to experience greater changes in speed which result in greater forces applied to your car. Ouch!***

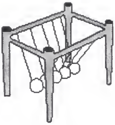
True or False. A heavy car and a light car collide head on. The force of impact is greater on the lighter car

(False. The force between them is the same.)

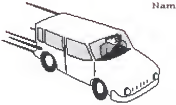
Apply **Newton's Third Law**—for every action there is an equal and opposite reaction. So the forces between two crashing cars are equal in opposite directions. Now, apply **Newton's Second Law, a = F/m**. Each car experiences the same force during the collision but the acceleration, or deceleration in this case, is much greater for the less massive car. Use the formula to help guide your thinking:

big car	**small car**
$F \div {\Large m} = a$	$F \div m = {\Large a}$

Extension



Have students explore a swinging-balls apparatus. Challenge them to answer this question: ***When two balls are released and collide with the remaining row of balls, why doesn't one ball emerge with twice the speed at the other end?*** (Momentum would be conserved but not energy. For energy to be conserved, **Kinetic energy** $(KE)_{in}$ must equal $(KE)_{out}$.)



Name ____________________ Period ______ Date ______

STUDENT ACTIVITY 4

Conservation: It's the Law!

Crash test question(s)

- Are bigger, more massive cars safer?
- Where does the energy "go" during a collision?

Purpose

- To describe a collision in terms of momentum and energy
- To infer how the law of conservation of momentum is applied in collisions
- To infer how the law of conservation of energy is applied in collisions

Materials needed for groups of two students:

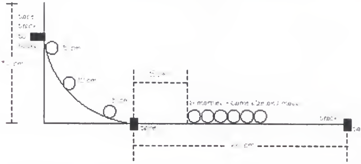
- pipe insulation track, 92 cm (3 ft.)
- 7 marbles, same size and mass
- masking tape, 30 cm
- meter stick
- books to support track (3–5)

Discussion

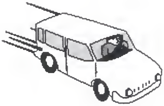
In the previous "Crash Course" activities, you have been studying how engineers use Newton's Laws and the concepts of momentum and impulse to study the physics of car crashes. Engineers at the Vehicle Research Center also rely on two laws that have been called the most powerful tools of mechanics (pun intended!), the conservation laws of energy and momentum. Let's explore the Laws!

Procedure

1. Using books as a support, tape one end of the track to a height of 25–30 cm. Using two more pieces of tape, create a flat, straight 60 cm rollway



2. Using small pieces of tape and a ruler, measure and mark the following heights on the upward curve of the track: 5.0 cm, 10.0 cm, 15.0 cm (measured straight up from the surface of the desk, not along the curve of the track).



"CRASH COURSE" ACTIVITY

Conservation: It's the Law!

STUDENT ACTIVITY 4

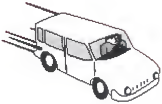
3. Place six marbles in the groove of the track. Allow about 15 cm between the end of the slope and the first marble in the line of six.
4. Push the marbles together so they all touch.
5. Place the last or seventh marble at the 5.0 cm mark on the upward slope.
6. Release the marble and allow it to roll down the track and collide with the row of marbles. Observe what happens! How many marbles roll away from the row? Record your observations in Data Table #1.
7. Place the marbles back in a row, making sure they all touch.
8. Repeat Step 6 from 10.0 cm and 15.0 cm using one marble.
9. Repeat Steps 6 and 7, with two, three, and four marbles.
10. Record results in Data Table #1.

Data Table 1

Number of marbles released	Height of release	Number of marbles knocked away from the row
1	5.0 cm.	
	10.0 cm.	
	15.0 cm.	
2	5.0 cm.	
	10.0 cm.	
	15.0 cm.	
3	5.0 cm.	
	10.0 cm.	
	15.0 cm.	
4	5.0 cm.	
	10.0 cm.	
	15.0 cm.	

Data Table 2

Height of release	Number of marbles released	Speed of released marble(s) before impact (slow, medium, fast)	Speed of released marble(s) knocked away (slow, medium, fast)
5 cm	1		
	2		
	3		
10cm	1		
	2		
	3		
15cm	1		
	2		
	3		
20 cm	1		
	2		
	3		



"CRASH COURSE" ACTIVITY

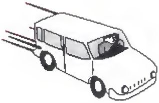
Conservation: It's the Law!

STUDENT ACTIVITY 4

11. Next, place the marbles back in a row, again making sure they all touch.
12. Place one marble on the 5.0 cm mark and release it.
13. Try and compare the speed of the released marble just before it collides with the row to the speed of the marble knocked away from the row (qualitative speed descriptions. slow, medium, fast.)
14. Repeat Step 13 at 10.0 cm and 15.0 cm with one marble.
15. Repeat Steps 6 & 7, with two and three marbles.
16. Record your observations in Data Table #2.

Analysis

1. Describe your results from Data Table #1.
2. Describe your results from Data Table #2.
3. Reviewing Data Table #1, how does the number of marbles and their release height affect the marbles' energy and momentum?



"CRASH COURSE" ACTIVITY

Conservation: It's the Law!

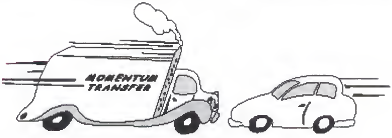
4. What conclusions can you make from Data Table #1 regarding the total energy of the released marble(s) and the total energy of the marble(s) knocked away from the row?

5. What conclusions can you make from Data Table #2 regarding the momentum of the released marble(s) just before impact and the momentum of the marble(s) knocked away from the row?

Crash questions

1. Describe the collision pictured below in terms of momentum, if the truck has four times the momentum of the car before the collision.

2. Describe the collision pictured below in terms of energy, if the truck has four times the energy of the car before the collision.



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BIOGRAPHICAL SKETCH

Tudor Griffith Jones, III was born in Mayfield, Kentucky, on June 9, 1961. His family moved to Naples, Florida in 1965 and he spent his elementary through early adulthood there. He received his Bachelor of Science degree in biology from Florida Southern College in 1983. He received his Master of Education and Specialist in Education in 1987 and 1995, respectively.

Mr. Jones is an assistant professor at the University of Florida's P. K. Yonge Developmental Research School in Gainesville. He has directed the research school's elementary science laboratory program and taught high school physics since 1987. He has served as principal investigator and lead teacher on numerous state and federally funded science education grants from agencies including the Florida Department of Education and the National Science Foundation. He has designed patented science education laboratory equipment and accompanying instructional materials for several companies and has published articles regarding innovative science teaching strategies in national science education journals.

In 1998, Mr. Jones received the Presidential Award for Excellence In Science Teaching from the White House and the National Science Foundation for his work in secondary education, and the Florida Association of Science Teachers' Outstanding Science Teacher Award for his work with elementary students and teachers.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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